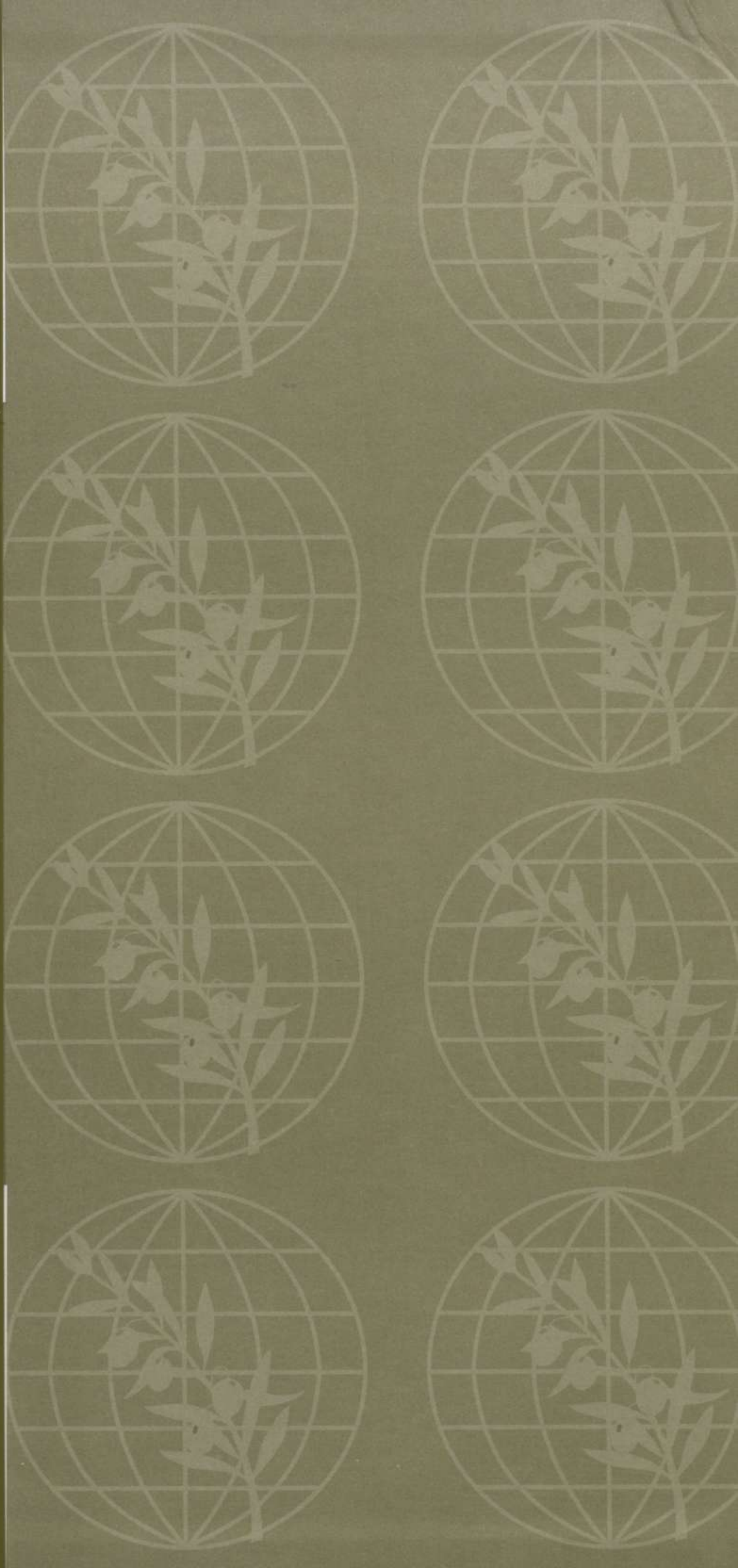
World Olive Encyclopaedia

INTERNATIONAL OLIVE OIL COUNCIL



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ANLUCA BOETTI

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All the opening photographs for each chapter are by Gianluca Boetti (except for Chapter 12).

We would like to express our thanks to the many collaborators who have kindly provided photographs, as well as the following museums – the National Museum of Archaeology in Madrid, and the Israel Oil Industry Museum in Haifa.

WORLD OLIVE ENCYCLOPAEDIA

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PREFACE

Dear Reader,

I have great pleasure in presenting the World Olive Encyclopaedia. This is an ambitious work that has taken some time to come to light; however, we trust that the laborious revision that has now been completed will ensure quality, at least that is our intention. I considered it both appropriate and necessary to extend the coordination and collaboration on the work to experts from the main producer areas of the world and to face with realism and determination the problem of the languages spoken in these countries – namely, Arabic, English, French, Greek, Italian, Spanish and Turkish. This is the first time in the history of olive growing that a publication has been produced in all these languages.

This was a difficult choice but I considered it necessary and in line with professional practice in that, for over thirty years, the International Olive Oil Council has been at the service of world olive cultivation, taking on all the responsibility of attaining this objective. It is therefore a source of great personal satisfaction that the Encyclopaedia has been produced under the auspices of the International Olive Oil Council which I have the honour of representing and for which I am responsible as head of the Executive Secretariat.

The publication of this work represents the first general and global compilation of all the latest knowledge in the field of olive cultivation and olive processing. We set ourselves two basic objectives: to draw up and to make accessible to both specialist readers and those who are starting out in the world of olive cultivation a compendium of knowledge in a single text. The subject matter is of prime importance for our Mediterranean countries and covers a broad range of topics – from culture to the economy – in a succession of situations, the origins of which go back to the early years of Mediterranean civilisation.

This is what makes the olive different from other agricultural crops and we have devoted the first chapter to the history and the presence of this tree in art and literature, thus symbolising the scope of the work as a whole. In this section of the book entitled «Evolution and History» and written by several authors, the reader will be able to go back over the history of the olive from the very start of its cultivation, discovering its various social, cultural and even religious aspects and finding out the extent of its significance – the olive was a source of mythical inspiration from the times of pre-Classical civilisation and later figured largely in the Greek epic.

As you will be able to see for yourselfes, the style of the Encyclopaedia is deliberately not uniform. It was practically impossible for there to be any type of continuity between such diverse subjects although all have the common denominator of the olive. In my opinion this heterogeneity is what gives meaning and full justification to a work that aims to embrace such a far-reaching and complex world with so many and such varied references.

In order to be accessible not just to specialists but to all types of reader and to be a valuable source of information and reference material, the Encyclopaedia aims to use simple and accessible language throughout, even when it describes complex scientific and technological facts. I cannot deny the difficulties we have faced in reconciling the necessary scientific rigour with a more general approach. This led to the need for painstaking revision and to an important consideration – the production of an inter-disciplinary glossary to be drawn up jointly by all the collaborators and which is to be included in a subsequent appendix to the work.

In this connection, I would like to call the attention of readers to another aspect which I believe is an essential and characteristic feature of the work – its diachronic programming according to which the Encyclopaedia is to be updated periodically by means of appendices covering the most recent achievements in the various disciplines. Our aim, which we trust will find favour with our readers, is to create a work of reference that is continually updated in the light of new considerations and is thus a valid and living tool for consultation.

In the hope that we have achieved this aim, I would especially like to thank the European Community for its understanding and for its decisive funding without which this work would never have been possible, as well as all those who have collaborated in it by contributing their valuable knowledge, in the conviction that our joint efforts have helped to reach our common objective – to safeguard, make known and promote olive cultivation in producer countries and in the rest of the world.

Fausto Luchetti

Executive Director International Olive Oil Council

SUMMARY

WORLD OLIVE ENCYCLOPAEDIA

Coordinated by the International Olive Oil Council - Madrid

Chapter 1

EVOLUTION AND HISTORY

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THE ORIGIN AND EXPANSION OF OLIVE CULTIVATION

José M. Blázquez

The origin of olive cultivation is lost in time and can be said to have developed alongside the civilisations of the Mediterranean Basin.

Ancient remains of olives have been found: fossils of olive leaves in Pliocene deposits in Mongardino in Italy; fossilised remains in strata from the Upper Palaeolithic period in the snail breeding ground in Relilai in northern Africa; pieces of olive wood and olive stones in Eneolithic and Bronze Age excavations in Spain. It can therefore be safely asserted that the existence of the olive tree goes back to the 12th millennium. The cultivated olive originated about six thousand years ago in Asia Minor. Of all the ancient peoples in that area, only the Assyrians and Babylonians did not know it.

The cultivated olive, *Olea Europaea L.*, comes from the wild variety, *Olea chrysophylla Lam.* via the *Olea oleaster L.* or *Olea europaea oleaster*.

Numerous remains and references testify to olive cultivation. Tablets were found in Ebla in northern Syria dating from the middle of the 3rd millennium and mentioning large-scale oil production. There are also records dating from the 2nd millennium BC in Syria and Palestina.

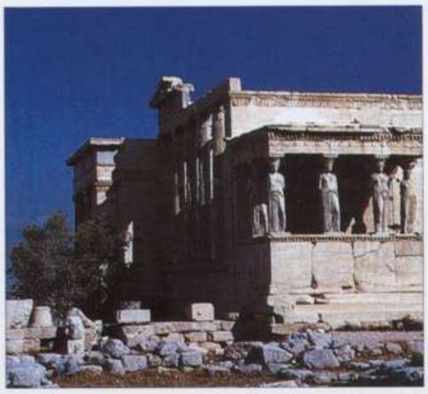
Olives were also cultivated in Anatolia, mainly on the Cilician plain, according to data in the Hittite texts and in Egypt, where it was imported from Asia. The olives that grew in the Nile valley in the Ancient Empire probably originally came from Syria. The Egyptian word «dt» is thought to come from a North Western Semitic language (zayt).

During the New Empire, olive groves had become fairly widespread as can be seen from an inscription from the time of Ramses II (1197-1165 BC) found in Heliopolis in the temple to the God Ra. This states that the olive groves around the city gave pure oil, the best quality oil in Egypt, for lighting the lamps in the sacred palace.

Sinuhe the Egyptian (1191-1178 BC), who lived for many years in a Syrian and Palestinian environment, mentioned the fine oil used in the prince's home. He also knew of using oil to protect the skin against cracks and sunburn. Perfumed oil was often rubbed into the skin.

Olive groves are mentioned on several occasions in the books of the Old Testament, such as Deuteronomy, Jeremiah, Hosea and Joel and oil was considered very necessary for health, according to the books of Kings, Chronicles, Ecclesiastes and the prophet Ezekiel. It is also stated that oil was used to light the lamps of the Tabernacle. The book of Ezra states that, at the time of the second Temple, after the captivity of Babylonia, Tyre and Sidon received oil in exchange for cedar wood. According to Ezekiel, the countries bordering on Phoenicia, such as Judaea, Damascus and Israel, provided oil for the Phoenicians, amongst other agricultural products.

As from the 16th century BC, the Phoenicians took olives to the Greek islands and from the 14th to the 12th centuries BC to the Hellenic peninsula where, by the 4th century BC, it had become a very widespread crop as can be seen by the fact that Solon issued decrees regulating olive cultivation.



Olive tree close to the Parthenon.

Tablets from the Mycenaean world dating from 1550 BC mention olives and they are believed to refer to both the wild and cultivated varieties.

Palaeobotanic traces found in Knossos (Crete) on a goblet dated by its shape from the early 15th century, are believed to pertain to a wild olive or a very primitive form of cultivated olive. Two types of olive stone have been conserved from the Minoan period (1900 BC); the one found in Slavokampo is similar to that found in Knossos whereas the other is possibly from a primitive form of olive. This duality in both olive fruits and olive trees seems to tie in with the duality of the ideograms representing them. The olives in Knossos were apparently used more for obtaining perfumes than as food. It has not been proved that the Myceaneans used oil for cooking but they probably did for lighting since lamps were common as from the middle Minoan period. However, these people did apparently include olives in their diet. There are numerous mentions in Pylos in Greece and just a few in Knossos.

In the first half of the first millenium BC, the olive spread throughout Assyria as shown in the Nimrod-Kalkhu findings, and the olive is mentioned in the Assyrian lexicons of the time. From the sixth century BC it was propagated throughout the Mediterranean Basin reaching Tripoli, Tunisia and the island of Sicily from where it was taken to southern Italy. Olive cultivation then spread northwards, from Calabria to Liguria.

The Romans spread olive cultivation throughout the Mediterranean coastal countries, as a pacific means of settling the country, so much so that, when they reached northern Africa, the Berbers already knew how to graft wild olives. Although introduced into Spain during the maritime domination by the Phoenicians (1050 BC), olive cultivation only developed under Scipio (212 BC) and during the Roman domination (45 BC).

MYTHS AND LEGENDS

Two Greek myths concerning the origin of olive oil are known to us. The great lyric poet, Pindar, (522-475 BC) who sang in his *Olympian III* the victory of Theron, the Sicilian tyrant, described the myth that the olive was brought by the Dorian hero, Heracles, from the country of the Hyperboreans (further north than the source of the Borean wind) to the Olympian sanctuary in Greece. The same myth was also reported in the second century AD by Pausanias in his *Description of Greece*.

In Rome, Hercules was still associated with oil, according to an inscription dedicated to him by the oil traders in the Forum Boarium and dating from the third century BC. At the end of the Republic, the oil traders dedicated a temple and a statue to «Hercules Olivarius» in Delos. The hero's club was believed to have been made of olive wood.

The second Greek myth attributes to Athene, the patron goddess of the city of Athens, the invention of olive oil and even the introduction of the olive into Attica. The god of the sea, Poseidon, competed with her to gain the sovereignty of the city of Athens and both gods tried to offer Attica the best possible gift. Poseidon gave a sacred lake to the Acropolis and Athene gave an olive tree. The council of the gods – or, according to other versions, a sentence given by Cecrops – determined that Athene was the winner because the olive could not only live for hundreds of years but it gave edible fruits and was the source of olive oil which could be used by men to dress their food, cure their wounds and diseases and light their homes.

CULTURAL AND ARTISTIC EXPANSION

H. Schäfer-Schuchardt

Lucius Junius Moderatus Columella was a Roman and an expert on agriculture in the first century AD. He was born in Cadiz in Spain and died at Taranto in Apulia, Italy. He valued the olive above all other trees saying of it «olea prima arborum est». The quote is from a voluminous treatise on agriculture, *De Re Rustica* V, 8, 1, written in the year 60 AD.

It is true to say that in classical times no other tree was so useful or valuable to the peoples of the Mediterranean, so much so that it was often treated as an object of veneration.

The olive is a symbol of wealth, fame and peace. The victors of both friendly contests and bloody wars were crowned with an olive wreath. The heads of the famous were anointed with olive oil and many people depended on it for their wealth and prosperity. Olive oil and olive fruits were then, as today, an indispensable food. Olive oil was also much prized as an ointment and fragrant oil. Death rites and worship of the gods would have been impossible to imagine without olive oil because it had become an essential element of religious ceremonies. Certain peoples, such as the Cretans (1,500 BC) or the Philistines (around 1,000 BC), owed their wealth exclusively to the products of the olive tree. As an export article, olive oil was traded in return for costly and rare items that could not be obtained locally.

The olive (*olea europea*) was described by the Greeks and Romans as the most important crop in the Mediterranean. Virgil, who was born in Mantua in 70 BC and died in 19 BC in Brindisi, recommended eating olives which he said were fruitful and fleshy and dedicated to peace; «*hoc pinguem et placitam paci nutritor olivam*» (*Georgics II* 425).

The Mediterranean is regarded as the cradle of our civilisation. It is also the historic home of the olive which therefore plays a fundamental role in the history of mankind. Everything we do to protect it and defend it serves at the same time to safeguard the universal values of our civilisation and culture. So it is not surprising that man very soon started paying serious attention to the olive – tending it, improving yield and oil obtention. Larger harvests and better quality oil brought increased profits, welfare and riches. This was recognised by the rulers of Crete whose wealth was based on olive cultivation and olive oil. In the midst of the olive groves scattered all over the island, the Cretans built splendid palaces in places such as Knossos, Phaistos, Vathipetros and Hagia Triada. Among the numerous frescoes which have been preserved in these palaces are some which depict olive trees. The frescoes from the second palace in Knossos are more than 3,500 years old and are probably the oldest representation ever of an olive tree.

Olive oil was Crete's most important export. Table oil and lamp oil were transported in medium-sized decorated *pithoi* and amphorae while the costly ointments and fragrant olive oils were sold in richly decorated flasks. Flasks such as these can be seen on a fresco in one of the storage chambers

Amphora for carrying oil dating from Roman times.

of the tomb of the Pharaoh, Ramses III (1184-1153 BC) in the Valley of the Kings, Luxor, Thebes. Proof of the high esteem in which olive oil was held is that the Pharaoh not only imported it during his lifetime but did not want to be without it even after his death.

Documents dating from the time of Ramses III and dedicated to the sun god, Ra, (the Harris I papyrus) relate the offering of first-class oil from olive groves at Heliopolis for the lamps in the sun god's temple. Numerous lamps, particularly those made of alabaster and found in the Pharaohs' tombs, show how olive oil was used in religious rites in the temples of Egypt. Egyptian death rites decreed not only that the bodies should be anointed with olive oil but also that they should wear an olive wreath necklace (Egyptian Museum in Cairo).

There are many literary references as well as illustrations on vases referring to the above-mentioned contest between Athena and Poseidon. Among the most beautiful is a Sicilian goblet dating from 400 BC which depicts the victorious Athena standing next to her olive tree while the vanquished Poseidon receives a consolation prize. Probably the most significant work was created by Phidias, the sculptor, between 447 and 438 BC. It was for the western pediment of the Parthenon temple at the Acropolis in Athens (Herodotus VIII, 55; Pausanias I, 24, 3 and 5; I, 26, 5; 27, 2; Ovid, *Metamorphoses* VI, 81). However, only parts of this have remained and they can currently be seen in the British Museum in London and the Acropolis Museum in Athens where a reconstruction has been built. It was also Phidias who sculpted for Olympia the statue of Zeus, one of the Seven Wonders of the World, and the most famous and splendid work of art of ancient times. It was carved from olive wood, gold and ivory. The head bore an olive wreath (Pausanias V, 11, 1). The statue was constantly rubbed with olive oil (Pausanias V, 1, 10) so that the ivory would not deteriorate in the damp air of Olympia. Herodotus, in his *History* V, 82, tells us that the Oracle of Delphi through Pythia, Apollo's priestess, once decreed that two statues should be carved from olive wood from the holy trees in Athens in honour of the fertility goddesses Damia and Auxesia.

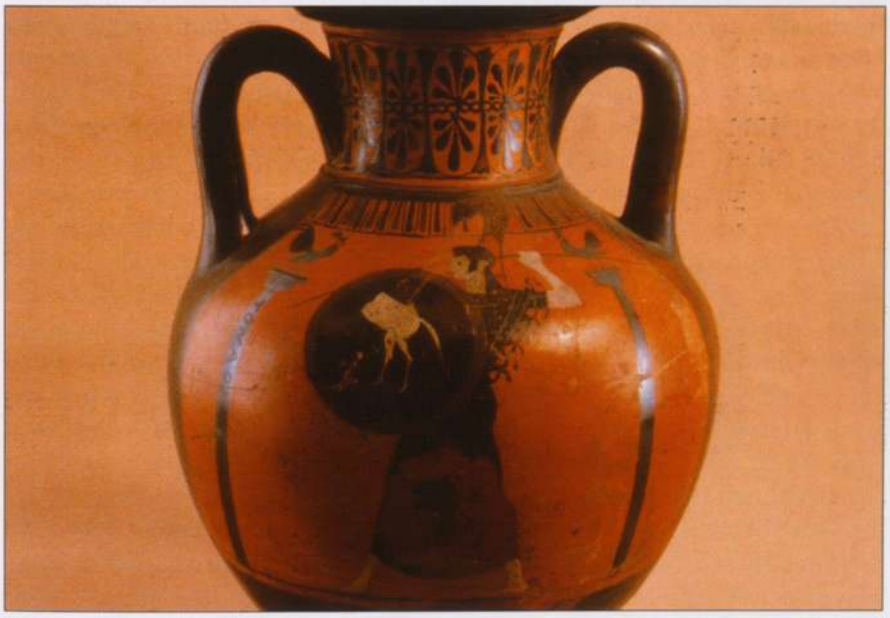
A solemn ritual act was the crowning of the Olympic winners with olive wreaths. These meanwhile stood ready on a small table placed in front of the temple to Zeus; decorated with gold and ivory, the table was a work of art by Colotes, a student of Phidias (Pausanias V, 20, 1-2).

The prizes for the winners of the Panathenaea in Athens held in homage to the city's patron saint and protectress of the olive tree, the goddess Athena, were also a great honour. The contests took place on Pallas Athena's birthday. The crowning moment was a procession of virgins wearing olive wreaths. They carried with them up to the Acropolis on a wheeled ship a garment they had woven and embroidered themselves known as a «Peplos». This was intended to dress the statue in olive wood of Athena on the eastern side of the Erechtheum. The whole procession is shown in detail on the Parthenon frieze (British Museum, London). The prize for the winners was olive oil obtained from the trees in the olive grove dedicated to the goddess Athena. The oil was handed to the winners in special amphorae showing on one ~~side~~ the goddess and on the other the sport in which the athlete had competed. The National Museum in Taranto has three of these amphorae which were awarded to an athlete from Taranto who took part in the Athens games in 480 BC. His trophies accompanied him to his tomb.


Crater from classical Greece.

Olive oil also played an important role in sport. In order to keep their muscles supple, athletes regularly rubbed down with oil in the gymnasia and wrestling rings. After the contest oil, dust and sweat were scraped off with a strigil. Both processes were favourite motifs in the paintings on Greek vases and sculptures. For example, a goblet from Capra decorated by Eutronius (510 BC) shows a scene of athletes rubbing down with oil. There is also a Roman copy in marble of a bronze sculpture by Lysippus who was an artist employed at the court of Alexander the Great (330 to 320 BC). It is the so-called Apoxyomenos, meaning a person scraping himself, showing a winner of the Olympic games cleaning himself in the classical way with a strigil.

Similar scenes are portrayed in the Greeks' death rites. For example, on a tomb dating from 430 BC in the Keramikos cemetery in Athens, a dead athlete is shown holding a strigil while in a burial scene on a goblet from Apulia painted by Ganymede in the fourth century BC a young athlete is seen holding a strigil together with a glass phial known as an *aryballos* containing olive oil. Olive oil was a constant feature of the Greeks' death rites. It


Amphora from classical Greece.

Pilgrim's ampulla from medieval times.

accompanied the deceased in costly vessels on their journey to the nether regions in decorated vases called *lekythos* that frequently showed scenes from the deceased person's life or the religious rites which took place at the graveside. It was also frequent for costly jewellery to accompany the deceased. Amongst the objects made of gold on show in the National Museum of Taranto there is a golden olive wreath that was found in the grave of a Patrician lady who died in the fourth century BC.

We owe it to the Greeks' and Romans' burial rites that numerous vessels have been preserved reflecting the incredible cult among Patrician ladies of the time of body and beauty care based on the use of an incalculable variety of fragrant oils and ointments. This went so far that sceptics claimed there was a specific fragrant oil for every single part of a woman's body! The cult gave rise to an enormous production of vessels for ointments and fragrant oils: they were made in a huge variety of shapes of pottery, earthenware, glass, bronze, copper, silver and gold. Frescoes such as one from Herculaneum dating from before 79 BC or the one in the Casa dei Vetti in Pompeii, dating from the same period, show how the perfume was made. Everything is portrayed, from the press to the application of heat and the addition of spices, right up to scenes where the perfume is tested in the shop. However, nothing could describe more poignantly the cult surrounding fragrant oils and ointments than the poem by the Greek scholar Callimachus who lived some time between 310 and 240 BC at the Ptolemaic royal court in Alexandria. The poem – an elegy to «Berenice's lock» – has been preserved for us in a Latin rewrite by the poet Catullus (*Carmen* LXI, 138, LXVI). It relates that Queen Berenice sacrificed a lock of her hair to the gods but, when it got to heaven, the curl wanted to return to its owner's head despite the fact that she had been very sparing in her use of costly perfumes. To make up for this, it was ordained that henceforth, before her wedding night, every bride should make an offering of perfume to Aphrodite.

Consecrated fragrant oils and ointments played an important role in Greece, the Near East and especially in Hebrew Palestine and also in early Christian Asia Minor, as in the consecration of oil on Maundy Thursday for the sick and for converts to Christianity. Anointment was a custom which spread to the whole of Christian territory. Kings, priests, altars, liturgical objects, sacred and profane buildings, the sick, bridal couples, newborns and the dead were anointed with consecrated oils. Both the Old and the New Testaments report upon this at length (Lev. **3**, 8, 10-12; I Sam.**10**, 1, **16**, 1, **13**; I Kings **1**, 39; Matth. **2**, 11, **26**, 7 etc.; John 12, 3, 4, 19, 41; Luke **7**, 37, etc.; **23**, 55-56; **24**, 1; Mark **16**, 1). The supreme example of anointment in the Christian religion is the anointment of Christ's body. The very words Christ and the Messiah mean «the anointed one». More than one hundred pounds of myrrh and aloe, spices and ointments were brought by Nicodemus and Mary Magdalene, Mary Jacobi and Salome to the burial. In the Holy Sepulchre in Jerusalem, the anointment stone at the entrance shows the place where Christ's body was anointed with oil and shrouded in linen. The scene of «Women at the Grave of Jesus» found its way into Christian art and became a favourite subject depicted in many churches. In Byzantine fashion it appears on a fresco from the grotto of San Vito Vecchio dating from about 1200 and now in the Museo Pomarici Santomasi in Gravina, Apulia.

In Asia Minor on the southern coast of Turkey another rite dating from early Christianity was typical. Saintly people who had died were buried in stone sarcophagi filled with fragrant oils. These oils were considered to have curative qualities and, for this reason, openings were left in the richly decorated sarcophagi, most of which had already been used in Roman times, from which such oil could be tapped or replenished as required. St Nicholas from Myra, Antalya, was buried in such a sarcophagus.

Olives were used in the ornamentation of a number of drinking vessels belonging to a costly silver set discovered during excavations in the Casa di Menandro in Pompeii that was buried when Vesuvius erupted on 24.8.79 AD. A total of 118 pieces can be seen between the Louvre Museum and the National Museum, Naples.

Innumerable oil lamps have been preserved for us from Greek and Roman times. Over the whole of the Mediterranean area and for more than 5,000 years, oil lamps were the ancient equivalent of electric lightbulbs lighting up homes, palaces, temples and churches. Finds in tombs and excavations and literary references offer a broad range. Probably the oldest description of an oil lamp, the golden Menorah with seven arms, is to be found in Ex.**25**, 31-40. Moses was instructed by God to provide such a lamp for the temple, in which only the purest of olive oil was to be used. In 70 BC the lamp was taken by Titus to Rome. The scene is portrayed on the Titus Arch in the Forum Romanum in Rome and on the mosaic floors of many Jewish synagogues such as the one in Tiberias-Hammath on Lake Genesareth dating from the fourth century and Bet Alpha in the Jordan Valley dating from the sixth century. The lamp burning permanently in front of the statue to Athena in the Erechtheum on the Acropolis in Athens was also very valuable. Pausanias (I, 26, 6-7) tells us that the lamp was made of gold by Callimachus who lived at the end of the fifth century BC. Once a year it was filled with olive oil. Homer, too, mentions a golden lamp dedicated to Athena (*Odyssey* XIX, 34).

In the Jewish religion, there were always two types of lamp, namely, the 8-flame Hanukkah which burnt for eight days, and the 8-flame Sabbath lamp which was lit on the eve of the Sabbath.

In early Christian times a popular custom was to hang from chains flat oil lamps that were richly decorated in gold and silver. Among the most ornate are the lamps from the St Nicholas monastery in northern Myra, Alacahizar, today to be found in museums in Antalya and Dumbarton Oaks.

Until the advent of gas lamps in the nineteenth century, oil lamps were to be found all over Europe. They were made in all shapes and sizes of earthenware, ceramics, glass, bronze, copper, lead, tin, silver and gold.


Roman lantern.


Roman lantern.


Roman oil lamp.

Roman bronze lantern.

Relatively prosaic events such as the olive harvest, olive pressing and the oil trade were often depicted on the ancient hand-painted containers. For example, an amphora from Vulci dating from 500 BC shows olive trees being beaten with poles, a vessel from Attica dating from the sixth century BC shows a beam press employing stone weights and an ancient Greek amphora, also from the sixth century BC, shows two scenes of olive oil traders.

It has already been stated above that many artistic objects were made of olive wood and there is a wonderful combination of poetry and handcraft in the description of the final recognition of Ulysses and Penelope in Homer's Odyssey (*Odyssey* XXIII, 177-204). Here, Ulysses describes a mighty olive tree from which he had carved a magnificent bedstead, the characteristics of which were known only to him and his spouse.

It should be added that in painting, too, olive trees have held a place of honour. For example, there is a fresco by Giotto in which a spectator waves from an olive tree during the entry of Jesus into Jerusalem (Cappella degli Scrovegni, Padua, 1305-1306) and a watercolour by Albrecht Dürer depicting an olive grove at Arco to the north of Lake Garda (Louvre, 1505-1507).

There are two trees in Paradise. One is the fig tree, regarded as the Tree of Truth. The other is described as the Tree of Life and this is the olive tree. Of course.

OLIVE OIL PRODUCTION: AN ORIGINAL HISTORY OF TECHNOLOGY

MARIE-CLAIRE AMOURETTI

It is very likely that the first mechanised agricultural implements were those designed to produce olive oil. The characteristic feature of olive oil production is that it requires only mechanical means. The process entails extracting a product which exists in its natural state in the fruit, without any chemical processes being involved such as those causing the fermentation of wine. It should come as no surprise, therefore, that archaeologists are now interpreting cavities and pounding devices found in Crete and the Middle East as Bronze-Age instruments for the production of olive oil (Eitam, 1987; Blitzer, 1992).

Olive oil production requires three operations:

– Crushing: bursting the skin and crushing the flesh
– Pressing: extracting the oil from the resulting paste
– Decantation: separating the oil from the vegetable water, solid elements and added water

PROCESSES USED IN ANCIENT TIMES

PRODUCTION WITHOUT PRESSING

If olives are crushed by hand in a bowl of water, a little oil is seen to float on the surface. This technique can be improved by using a simple stone pounder and adding hot water. This is olive oil production using a mortar, the 'washed' oil of the Bible that was favoured for religious purposes and was produced in small quantities. Oil yield can be further improved by treading the paste underfoot after initial crushing. Hot water is often added at the end to facilitate decantation. An example of this method is the *zit Uberray* oil, which is still produced in the 20th century by women in Kabylia.

With the treading and wringing method, the olives are put in a bag and trodden in a tub. A rod is then inserted at each end of the bag and the oil is wrung out by twisting the bag. This method was known in the Egypt of the Pharaohs, probably for vegetable oil, but certainly for wine (Montet, 1925, Meeks, 1993). In the modern era, it is attested in Venice and Spain and was still in practice in Turkey and Corsica in contemporary times (Casanova, 1990; Mattozzi, 1979; Gonzalez Blanco, 1993).

Pre-neolithic stone with cavities for clay bowls from the Nahal Orem site.

Stone rollers from the Second Bronze Age from Tel Beit Mirsim.

THE APPEARANCE OF THE MILLSTONE

Crushing was for a long time carried out using a large stone or by treading. Then, in the Bronze Age, stone rollers were introduced which were pushed manually or using wooden supporting frames. These were the forerunners of the crushing cylinder that, in some cases, may have been turned by an animal. The invention of the perpendicular millstone is very important because it was the first rotary movement to be used in a processing mechanism. The oldest remains of such an apparatus were found in Olynthus, a city in northern Greece, and date from the 4th century BC. This machine is like the *trapetum* described by Cato in the 2nd century BC. The *trapetum* was operated manually, and several of them have been found, including one in Pompeii. The system requires precision design because the millstones crush the olives against the wall of the mortar, and must therefore be exactly the right size. Several types soon appeared: perpendicular millstones, the *molae oleariae*, with one or two millstones, crushing the olives against the sides and the base of the recipient. These were widely used during the Roman period (Frankel, 1986, 1992; Brun, 1986).

THE APPEARANCE AND CONSOLIDATION OF PRESSES

The simplest way to press olives is to place a stone on the crushed fruit flesh and wait for the pressure to take effect. Machinery proper arrived as soon as the stone was suspended from a beam. Archaeologists have found many stones hollowed into a sort of trough into which bags full of olives were placed, similar to the olive pressing mats of Provence.

Oil presses can be classified according to the type of pressure applied (Parain, 1960):

Wedge presses
Beam presses – with single counterweight
– with fixed winch
– with winch on counterweight
– with screw on counterweight
Direct screw presses – with two screws
– with one screw

All these types were known at the beginning of our era. During the Roman Empire they spread throughout the Mediterranean world because of an increase in demand and in olive oil production (Mattingly, 1988; Hitchner, 1993). Regional differences are perceptible. One of the major mechanical problems of this machinery was the risk that pressure might cause wrenching. The ways in which the beam was embedded therefore varied: wooden posts, the *arbores* of the Latins which are deeply recessed in Italy, or stone monoliths which resist by their own weight in Cyprus, Dalmatia, and Maghreb countries for example. The shaft was also sometimes recessed in a wall, which limited the possibility of shifting. When a cave oil mill could be used, resistance was greater and this system was used in the Lebanon and Judea (Callot, 1984; Eitam, 1987; Kloner Saguiv, 1992).

Wedge presses are seen in a painting in Pompeii. They were probably used to produce oil for use as a perfume base.

The last improvement to beam presses in ancient times was the screw. Fixing a screw on the counterweight meant less work and greater safety. This system, which was widespread especially in the Late Empire, was very common in the Middle Ages. It was further improved by using pins for what is known as the large-point press (Frankel, 1993; Amouretti, Comet, Paillet, 1984). Direct screw presses appeared just before our era, but did not replace the others. Although they afforded more direct control over the pressed oil, they were also fragile and required more labour. As they were made of wood, there are fewer remains of such presses. They could have one or two screws and were probably more widespread than has so far been assumed. All the technological changes were thus introduced during antiquity. Certain points were further improved in medieval and modern times. The *trapetum* made way for a larger millstone, but the cylinders remained. The productivity of the beam press was improved and attempts were made to improve the size of the direct screws.

DECANTATION

Being lighter than water, oil floats and can be collected by hand or with a sort of flat spoon. All decantation systems have therefore used water, either in large earthenware jars – the *pithoi* of the Greeks and the *dolia* of the Romans – or in stone cisterns (Brun, 1992). The most beautiful decantation tanks are those of North Africa with a succession of communicating cisterns (Camps, see below). It was apparently quite late, probably in the 16th century, that people thought of recycling the olive pomace by repeating the pressing to extract more oil, although of inferior quality, from the residue (Bernard, 1786; Magnan, 1985).

LATER CHANGES

As the Abbé Couture pointed out at the end of the 18th century, most direct producers were much less concerned with quantity than quality. Except where very heavy shaft systems were used, productivity was not very great, and every effort was made to improve it. For example, the olives were left to drain for several days or even boiled before being put in the bags. It is interesting to note that Latin agronomists such as Cato and Columella were concerned about the quality of the olives and of the oil. They recommended careful harvesting without beating the trees, rigorous cleaning of the equipment before and after use, and rapid pressing after the harvest. The same concerns were expressed by agronomists in the 17th and 18th centuries, when a veritable campaign was conducted to improve both the profitability

Oil mill restored in the 20th century.

of the products and the quality of the oil. At this time olive groves and olive oil mills began to spread all over Corfu (Sordinas, 1971), the direct screw press became established in Italy and efforts were made in France to improve productivity by housing the press in vaults. Agronomists were wondering about certain 'technical' barriers. For instance, the agronomist Bernard stressed the reticence of the nobles, who owned the oil mills, to improve pressing because it was they who kept the pomace. Improvements were being proposed everywhere, such as the winch to turn the screw. Some of these proposals were not viable (Bella, 1784), but they do point to a great concern for improvement. At times, hydraulic power was harnessed for the crushing (Amouretti, Comet, 1989).

Nearly all the pressing systems invented in antiquity still co-existed at the beginning of the 19th century: wringing, crushing in a mortar, beam presses with simple counterweights, screw presses, or direct screw presses. Whereas presses with a winch, or with a winch on the counterweight, disappeared for oil production, the others remained. Indeed, they sometimes co-existed in the same country or the same region. Their shared characteristic was that they were made of wood or stone. This co-existence was not due merely to complacency, which is the usual facile explanation. Each method has advantages and disadvantages, and a changeover had to be carefully considered. Amongst the changes which occurred in the 19th century and the beginning of the 20th, the most significant was the massive extension of olive cultivation in certain countries, such as Greece and Turkey. In ancient olive-growing countries like France, Spain and Italy, efforts were made to gain ground on terraces, and competition from seed oil started up at this time. The production of metal machinery meant that screw presses took precedence. They were smaller but stronger and the main drawback, that of the pressure causing breakage, bursting or wrenching, was partly eliminated. But the oil producer could no longer build his own equipment. (This is why some beam presses constructed in situ remained in operation until the 20th century). The drop in manufacturing costs of small presses during the second half of the 19th century also facilitated their consolidation. However, these improvements did not constitute a real technical breakthrough and the systems invented in ancient times were only ousted when the centrifuge appeared on the scene.

CONCLUSION

While the history of wine-making techniques has been the object of much attention, oil production techniques have been somewhat overlooked (Amouretti Comet 1989, 1993) in spite of the fact that they are most instructive. It was for olive oil that the first shaft presses, vertical millstones and perhaps the first screws were invented. Furthermore, a certain number of simpler, at times family-centred practices, were preserved through the centuries in the processing operations. They were able to offset one of the major drawbacks of olive oil production, namely the characteristic irregular bearing and the obligation to press the olives soon after harvest. The permanent risk, even now, of not being able to meet demand was sometimes countered by such simple, family-centred systems, although this restriction is inevitable with speculative crops. Finally, certain types of production were retained for reasons of religious convictions. Our history of olive oil production techniques has therefore necessarily referred to social systems, the mythical aspects and the economic role of the olive tree since ancient times.

OLIVE OIL CULTIVATION IN NORTH AFRICA

Henriette Camps-Fabrer

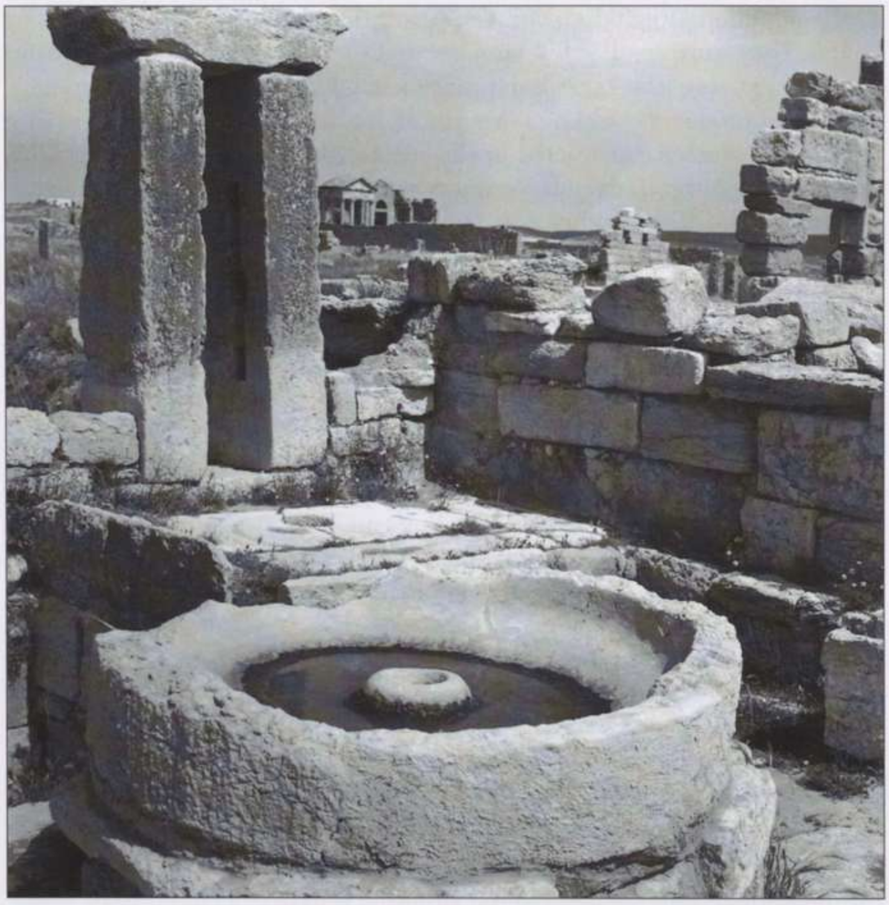
The presence of *Olea europaea L.* has been proved since the Villafranchian Stage in the Sahara and since 12,000 BC in North Africa. When the Romans arrived, the Berbers already knew how to graft wild olives and the cultivation that the Carthaginians had begun was to be considerably expanded by the Romans.

THE ROMAN PERIOD

NATURAL CONDITIONS AND CULTIVATION PROCEDURES

The Romans were quick to understand that the olive was the ideal tree crop for the Tellian regions where it could enjoy the excellent climate. The olive is especially demanding with respect to soil conditions which must be neither too clayey nor too sandy.

The Romans grafted the wild olives making them productive, and developed transplantation. On light soils with level surfaces, the trees were planted, as



Roman oil mill along a Roman road in Sbeitla Suffetula (Tunisia).

Cylindrical counterweight in the Roman archaeological site in Ceuta.

in Henchir Hadj Gacem in Byzantium, an average of 15 metres from each other. The olive requires minimum care (Pliny the Elder, *Natural History* XVII 45, 28; Columella, *De Re Rustica*, V-IX); water, tillage at least twice a year (a scene of tilling in an olive grove is depicted on a mosaic in Cherchel), removal of the suckers and fertilisation every three years.

The Romans had two tasks: they had to find the way for farmers who had planted olives to live while waiting 10 years for their orchards to become productive, and they had to ensure peace.

THE OLIVE-GROWING POLICY OF THE ROMANS IN NORTH AFRICA

During the Republic and in the first years of the Empire, Rome, preoccupied by the long and difficult struggle against the Musulamii in particular (Tacitus, *Annals* II, II and IV), does not appear to have devoted much attention to developing this crop. In Caesar's time, the olive had not yet started to spread even though the *Lex Manciana* had encouraged olive cultivation. The policy of the Julio-Claudian and Flavian dynasties was overshadowed by that of Antoninus and Severus, the latter being himself of African origin. These made positive efforts to boost olive cultivation, as can be seen from the Henchir Mettich inscription offering benefits for anyone planting olive trees and the one in Aïn-el-Djemala in which farmers requested permission to grow olives on lands that had hitherto been unused. Two epitaphs found, one in the *Fundus Aufidianus* (Peyras, 1975) and the other in Uppena in north Bizacène, prove that the boom in olive growing in Northern Tunisia appears to have continued, at least in part, well into the Later Empire. The Albertini Tablets (1952) prove that at the end of the fifth century the olive was still the main crop as far south as Djebel Mrata. The olive therefore brought fortune to the African provinces, especially because a shortage of oil in Italy led to the export of African oil.

THE OLIVE AS A CONTRIBUTION TO PEACE AND SETTLEMENT

The olive thus became one of the peaceful methods of encouraging settlement. Olive-growing tied the inhabitants of the steppes to the land and checked nomadism up to the edge of the desert (Baradez, 1949).

Hydraulic works

Terraces were constructed along the wadies, and reservoirs facilitated irrigation in the driest areas. In Djebel Mrhila in central Tunisia (Barbery, Delhoume, 1982), a Roman plantation was discovered which clearly showed that the ancient planting holes dug in the limey crust allowed the root systems to draw their nourishment from lower, lighter soils.

The ruins of oil presses and mills found in the country and in towns have made it possible to draw up a map of the most important oil-producing regions in Roman Africa. Proconsular Africa remains the largest olive-growing region; cultivation was less widespread in Mauritania Sitifensis and decreased increasingly to the west; this corresponds to the deepest penetration by the Romans in the eastern part of North Africa.

Systematic prospections reveal the density of land use. For example, near the town of Caesarea on an area of 300 km$_2$, 54 olive-growing farms were found on 241 identified sites (Ph. Leveau, 1982). Similarly, in the Hallail wadi valley, between Djeurf and Aïn Mdila on the southern slope of the Nemenchas, numerous oil mills constitute part of the major olive-producing region of Southern Numidia (Ph. Leveau, 1974-5). In the Azeffoun/Tigzirt region in Great Kabylia, about one hundred oil mills dug in the rock were found next to 50 classic oil presses (Laporte, 1983). Finally, the town of Volubilis alone (in Morocco) boasted more than 50 oil mills (Etienne, 1964; Ponsich, 1980; Kherraz and Lenoir, 1981-82). The olive tree came to occupy southern lands which today are buried under the sand, such as the town of Gemellae.

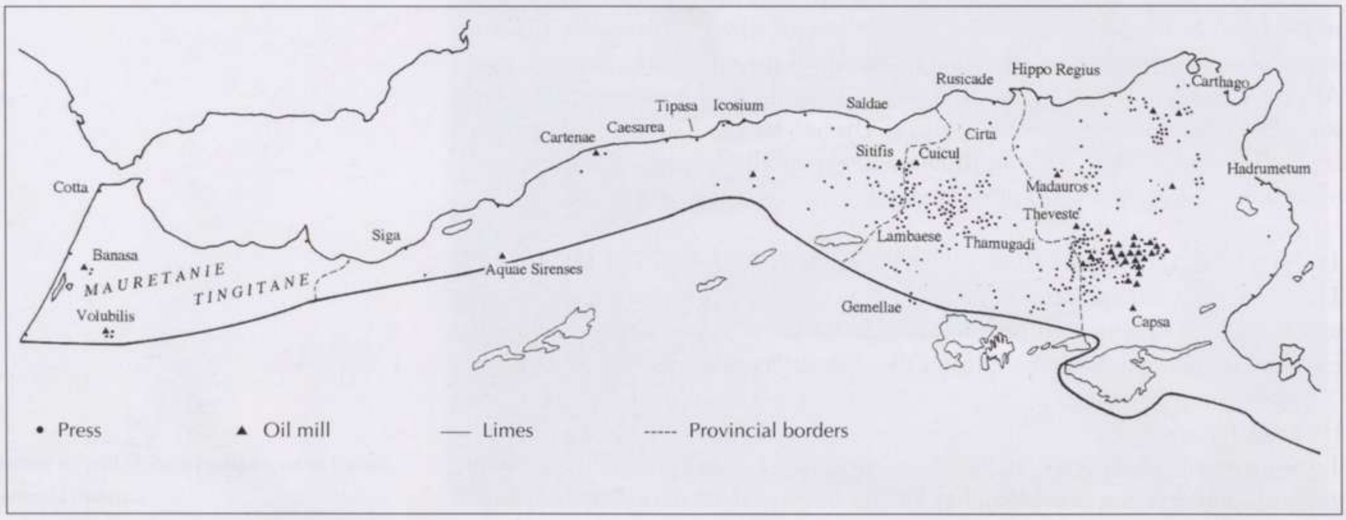
Mills and presses

After the olive harvest, which was often depicted as a symbol of the first tasks of the winter (the Utica mosaic, the Julius mosaic in Carthage and the painting in the Hadrumetum necropolis) (Prêcheur-Canonge, 1963), the olives had to be crushed by one of several methods.

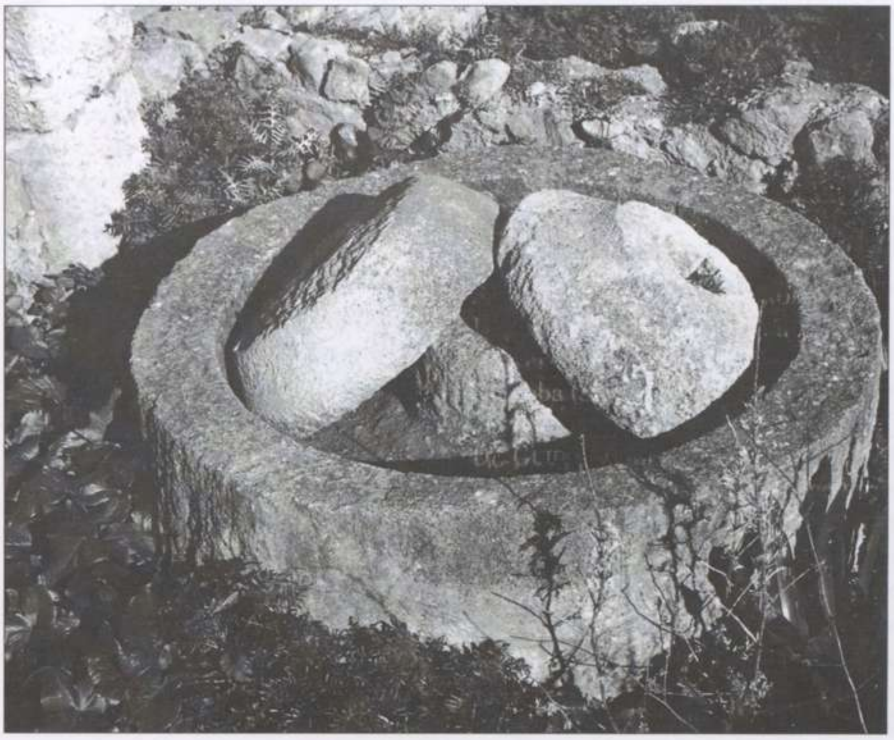
J. Laporte (1974-75) has suggested that the spiked «bronze bludgeons» were used for crushing olives (Columela, *De re rustica*, XII, 52, 7). The *mola olearia* was less efficient than the *trapetum*, a round tank with a short stone column in the centre supporting a rectangular piece of wood covered by metal plates and turning on a wooden pivot (*columella*).

The Berber mills in the region of Fez and Aures are similar to the Roman mills.

Olives could also be pressed with the wedge press used until recently in Tkout in the Aures region.



Map showing the location of oil mills and presses in Roman Africa.



Oil mill in Tipasa (Algeria).

But the most widespread press was based on the principle of pressure exerted by a beam (*prelum*) driven by a winch solidly fixed to a counterweight with two dovetailed notches at either end. There were also screw preses with a cylindrical counterweight, and rudimentary presses carved in rock have been found in Great Kabylia (Laporte, 1983).

A distinction should be made between industrial concerns comprising more than 20 pressing platforms, urban mills and small family mills.

FROM THE MIDDLE AGES TO TODAY

By the time of the Muslim conquest in the seventh century, the Vandal and Byzantine domination had already damaged the countryside and the enthusiastic descriptions of the Maghreb as a sea of olives should not be taken too seriously.

In the ninth century, under the Aghlabites, the geographer El Ya'qubi wrote that the olive reigned supreme in the area of Sfax. It was to survive the Fatimite crisis but El-Bekri stated that in Kairouan olives were cut down for firewood.

The Hilalian invasion in the ninth century was described by Ibn Khaldun as an invasion of locusts. The gradual reconquest by the nomads of the territories that had been so laboriously settled under the Romans was the final blow to olive cultivation. During the Turkish period or the French colonisation in which, according to P. Bourde, olives were replanted in certain areas such as the Sahel in Tunisia, the high plains were used for cereal cultivation and the western areas for vines.

So it can be categorically stated that olive cultivation reached its peak during Roman times when the olive branch was more than ever a symbol of peace.

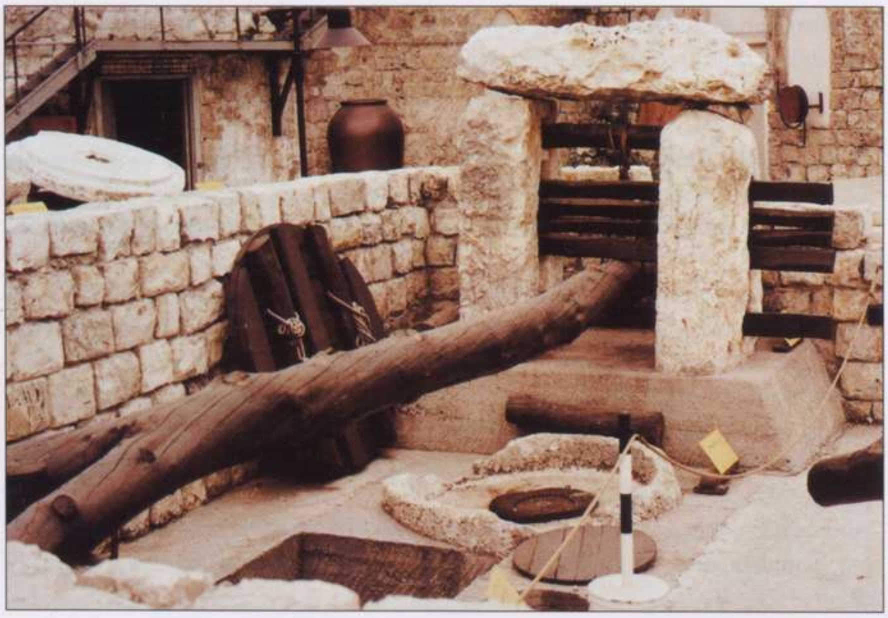
OIL AND THE OLIVE IN TINGITANIA

MICHEL PONSICH

The agrarian animism of ancient Barbary is revealed in Mauretania Tingitana and persists in the deep roots of its ancient culture through certain rural religious practices. The prime preoccupation of this primitive rural world was that rain, the male element, should impregnate the soil, image of the female element. Useful territories were determined according to these basic precepts. They were naturally situated in areas that were suitable for permanent human settlement and for farming cereals, vines and olives.

According to Pliny, oil and wine are gifts that nature could not refuse Africa which had been totally entrusted to Ceres. In Tingitania, the wild olive tree adapted easily to the gently sloping land and foothills of the mountains. Between Er Rif in the north, the Medium Atlas in the east and the High Atlas in the south, this useful territory of early Morocco was influenced first by the Iberians and Carthaginians and then by the Romans. It forms a triangle between Tingis, Volubilis and Sala in the south, largely facing onto the Atlantic. The Phoenicians and Carthaginians made their first decisive contacts with the native Numidian population along this straight stretch of coast where they set up trading posts that were to be basic to the commercial development of the whole country.

The first evidence of the olive tree found in this region – in a necropolis near Tangier – dates from this period of cultural change. Olive pits were placed as an offering in the grave of a farmer from the 7th century BC. The local inhabitants probably began to cultivate wild olives with the help of the Ibero-Phoenicians who taught them how to graft.



Restoration of an oil mill with a beam and screw: two arbors support the *unculum* of the *prelum*, *ara* and *orbis olearis*.

Zitoun and *zite* (olive tree and oil) are rustic names of Semitic, probably Phoenician, origin. This root suggests that the local people, under the influence of the Phoenicians, had already learnt by the 7th and 6th century BC of the benefits of the olive tree and introduced olive orchards into Tingitania. The local rural structure developed during the Punic-Mauritanian period and the oil trade contributed to the economic growth of the cities of Juba II. The expansion of olive cultivation was carried out by the Maghrebis but of undoubted importance too was the influence of Baetica (southern Spain), a land of exuberant vegetation where the sun and the olive seem to go hand in hand.

From the start of the Roman occupation of Tingitania, the importance of olive-growing led to an impressive number of isolated rural sites round the main urban centres. The current state of archaeological research in Tingitania confirms unequivocally certain facets of daily rural life. In the region of Tingis, Lixus, Sala, Banassa and Volubilis, archaeological surface prospection has formally identified the extent of occupation of rural areas where olive oil production played a leading role. Most of these settlements (250 or so) were located on lands suitable for the cultivation of the olive. In line with the traditional organisation of *villae rusticae*, they were each likely to have had their own oil mill. Traces of olive presses and fragments of basins, press counterweights and *prelum* supports found on the surface all point to the existence of such mills. They also confirm the obvious strategy behind the rural policy dictated by Rome, from a country that intended to benefit from the local agriculture. Few of the Tingitanian towns have been excavated so far. Nevertheless, the remains at Banassa and especially at Volubilis indicate the strength of the olive oil trade and its consequences for the prosperity and enrichment of these two towns.

The origin of Volubilis is attested since Neolithic times. People settled on a spur at the foot of Mt Zeroun to benefit from the natural environment. These sunny soils are an ideal cradle for the olive and there is abundant evidence of olive oil production. The 40 hectares inside this walled town, possibly the *Regia Jubae* of Tingitania, were remarkably well-developed. The size of its *decumanus*, its public monuments, courts, forum, capitol, baths and triumphal arch clearly indicate a desire to emulate a Roman town and the rich local inhabitants were able to satisfy this desire. The vast halls with their shining mosaics, furnished with precious objects imported from Baetica, Gaul or Rome, afford an idea as to the standard of living and of the taxes that well-to-do farm owners were able to pay. More than a third of the city has been excavated, including a residential quarter, where nearly all the large homes had an oil mill, at times with several presses, and huge tanks for olive oil.

This urban production capacity, together with that of the numerous presses in isolated *villae* in the surrounding countryside, points to the size of the Volubilis olive orchards. The other towns of Tingitania seem to have been equally suitable for olive cultivation and orchards probably grew around Tingis, Banassa, Lixus and Sala and in all the villages adjacent to the country's numerous camps. It is clear that Tingitania depended to a fairly large extent on olive cultivation. Each of the towns, although they have not yet been excavated, probably had its own source of income, frequently based on this lucrative activity. The development of Volubilis and Banassa, the public buildings found in Lixus and Sala, or those still remembered in Tingis, all bear witness to a rich province. And olive-growing undoubtedly contributed extensively to their development and prestige.

Unlike Spanish oil, the oil from Africa had a bad reputation, according to Pliny, although he contradicts himself when he alludes to a sort of sweet olive oil found in Africa. If Caesar was able to impose heavy taxes in the form of olive oil from the African provinces for daily distribution in Rome, then this oil must have been up to Roman standards.

The proximity of Tingitania to southern Spain, the geographic and climatic similitude, technical similarity in the layout and construction of oil mills together with age-old influences all meant that these two provinces shared many aspects of olive cultivation. Dressel 20 oil amphorae from Baetica found in Tingitania, although not very numerous, prove that the Mauritanians were able to compare the different oils and thus try to raise the quality of their production. The presence in Hispalis (Seville) of an official to register the oil from both Africa and Hispania suggests that the oil from Tingitania was of such quality as to form part of this trade. An *adiutor* in charge of the *annona* (crop) supervised the quality of the oil in transit through Seville to ensure that there was no shortage of good oil in Rome.

In the fourth century AD, a law passed by Honorius alludes to the oil supplies from Africa intended for Rome. At that time, Tingitania was still occupied and the oil presses continued to be the reason for constant comings and going between town and country, enabling olive oil to play its timeless role.

The oil from Tingitania never had the prestige of the oil from Baetica but there is no doubt that trade in oil contributed to the economic growth and aesthetic development of the towns of Tingitania and that it was traded in Seville.

OLIVE CULTIVATION IN ANCIENT ISRAEL

DAVID EITAM

The olive tree and olive oil were a major component of the culture of Ancient Israel and the economy of its inhabitants. Its prominent status is revealed by dozens of verses in the Old Testament and numerous references in late Jewish literature. The olive tree served as a symbol of beauty (Jer.**11**.6), freshness and fertility (Ps.**52**.10) – «Your sons are like shoots of olive around your table» (Ps.**128**.3). In the Jotham fable, the olive tree was the first to be chosen as king (Jud.**9**.8). The land of Israel and the olive tree are one – «land of oil olive» (Dt.**8**.8).

Unlike the grapevine, the attributes of the olive do not figure largely in the place-names of ancient Israel, merely because «olive trees will be growing everywhere» (Dt.**28**.40) and they indeed were. The Holy Land is one of the homelands of the cultivated olive (*Olea europaea*).

Oil mill.

Botanists can determine from olive fossils between the wild olive (*O. europaea L. var.*) and the cultivated olive (*O. europaea*) (Kislev 1984). The earliest wood remains of olive trees were found in the desert highlands dating from around 42,900 BC. The wild olive tree continued to be a significant element in the Mediterranean woodlands, as is proved by the common use of olive wood for buildings in the protohistoric and ancient periods (Liphschitz 1994). It was forbidden to cut down the cultivated olive because of its economic importance and there are many documentary references to such protective measures (Mishnah Kila'im 6:5).

The first appearance of groups of cup-marks – small cavities chiselled on rock surfaces – in epipalaeolithic sites (10,500-8,300 BC) may signify the first taste of olive oil by man. These were undoubtedly designed for crushing cereals and producing liquid (although not necessarily only olive oil) and they increased in numbers during the pre-Pottery Neolithic period (8,300-6,000 BC). In many sites, deep concave mortars have been found close to them. Both apparently served for producing oil using two primitive techniques.

The first conclusive, although rare, evidence of the production of olive oil dates from the Calcolithic period. A basin buried in a clay layer on the slopes of Mount Carmel was found full of dozens of olive pits and much organic material (Galili, forthcoming). Oil was certainly extracted there by means of an ancient method called *shemen rahutz* (washed oil, in Ancient Hebrew) or *zeit tafah* (smeared oil in Arabic) (Dalman 1964, Eitam 1993).

Olive trees were first cultivated in Israel during the second half of the fourth millennium BC in small villages in the Mediterranean regions around the Golan woodlands where the first separating vessels have been found (Epstein, forthcoming) and in the hills of Samaria (allowing an annual consumption of at least 5 litres of oil per person). Dozens of rock-cut mortars with collecting-bowls prove the existence of primitive olive processing (Eitam 1993). In the mortars pure oil was manufactured by crushing the olives. This method yields small quantities (6% oil) of high quality (95% oil content) «pure crushed olive oil» – *shemen zeit zah katit* (Lev.**24**.2).

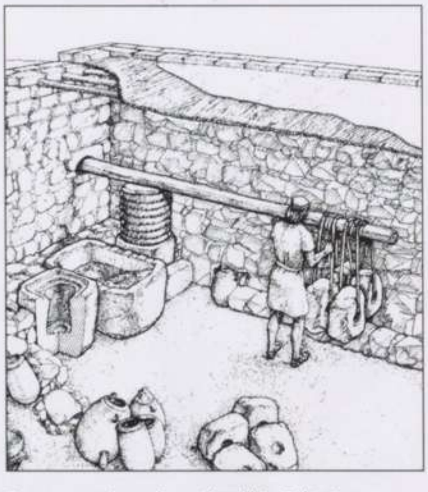
With the beginning of settlements in the early part of the third millennium BC, horticulture expanded and developed. The growth in population and the improvement of the metal axe made it possible to cut down the forests in

Simple oil press (10th-9th century BC), Bar-Zredah site.

mountainous regions and prepare the ground for olive groves and vineyards. Although oil and wine could technically be produced with the same equipment – the collecting vats for both had the same biblical name of *yekevim* (Joel **2**.24) –special installations for each product were discovered side by side in a fortified settlement from the Early Bronze Age (Eitam 1994, Zertal, 1992). Only a dozen small installations and some ceramic vessels with spouts to decant oil have been identified so far in Bronze Age sites but historical documents enlighten us on olive cultivation. For example, 30,000 litres of oil were ordered by Egypt from Cana'an in the fifteenth century BC; the Land of Yaa in the Levant is described thus, «abundant was its honey, plentiful its oil» (Tale of Sinuhe). An indication gives «'b3k (several kinds of olive oil) in the harbour» in the Anastasi papyrus IV.15.4-5 (Stager, 1985). Such documents and the existence of hundreds of jugs and jars of Syro-Palestinian origin in Egypt in the new Empire indicate the extent of production and export of olive oil (and wine) from Cana'an during the third and second millennia. A few large-scale installations (dating from the Mb and IA I periods) found at Mount Manasseh and Tel Yokne'am (Eitam, 1994) provide industrial and archaeological continuation of this phenomenon. The olives were trodden by foot, wearing wooden shoes (Yungst and Thielsher 1957) or were crushed by millstones. The use of a beam lever was only introduced into olive processing around 1,500 BC, as proved by the finds at Ras Shamra, the capital of Ugarit (Callot 1993) where about 5,500 tonnes of oil were manufactured per year (Heltzer 1987), and in the palace of Tel Hazor in the LB period (Eitam, 1994a). From the thirteenth to eleventh centuries BC, production declined but primitive methods for producing oil continued with basins similar to the Chalcolithic mortars.

Olive processing was first carried out on a large scale in the Iron Age II, as demonstrated by more than 100 typical beam presses with a central collecting vat. The mill had two presses and a basin (where olives were crushed by a roller) operating simultaneously. Separation was carried out in vats, rock-cut round basins (Israel) or in pottery vessels from which the liquid or oil flowed through holes pierced in the bottom or upper part of the walls (Ekron). Between olive harvests, the equipment served for textile or flour production. In the Kingdom of Israel, industrial villages, possibly royal villages, were specially built such as those in Kla' and Kh.Khadash which produced large quantities of oil. The kingdom-city of Ekron in Philistia became in the seventh century BC an olive oil enterprise of unprecedented strength in the ancient world (it was probably established and operated by the Assyrians) (Eitam 1994b). Private production by small farmers (Eitam 1990) and certain affluent farmers who owned big estates (II Sam.**17**.27) continued. The Galilee region did not share this mass production. Only a few relatively small lever and weight presses (about 80 kg as compared to the 400 kg of the Ekron press) dating from the 10th to the 8th centuries BC have been found there. The complex included a crushing basin and a press bed both draining to a collecting vat and separation basin. This type was brought by the Phoenicians to their colony in Tell Shiqmona (Elgavish 1970) and to the administrative but also industrial royal centre of the «Land of Kabool» given by King Solomon to King Huram of Tyre (II Ch.**8**.2) (Gal and Frankel, 1983; Eitam 1994a).

The relations between the Mediterranean countries are not yet completely clear. It seems that early manufacturing activities (Neolithic period) developed simultaneously in several cultures. It seems plausible that the lever invention originated in Syria and spread through Cyprus (Hadgisavvas 1992)



Reconstruction of an oil mill in Tel-Migne (Israel).

to LB Crete (Melena 1983). Probably olive cultivation and processing was well established in classical Greece, as attested in literature and art. Two beam presses have been found – one with a stable wooden stand and sack-weights full of stones (Beazley 1956), and the other with a fig-shaped press bed and special weights – both chiselled in stone blocks (Paton and Myres 1898). Archaeological dating and the images on Attic stelae (Foxhall, 1994) show that varied farming activities existed simultaneously in the rural sector (similar to those in oil production in Israel although not centralised mass production as such). More technically developed and organised production took place in cities such as Olynthus where at least 3 mills have been found (possibly from the Levant). It is not yet clear when olive processing was introduced (probably by the Phoenicians) to the western Mediterranean.

During the third century BC, the centre of oil production moved to the Sidonian colony of Maresha, where 20 oil press caves were carved in the soft limestone around the city. The oil mills (*mortarium* and one *orbes*) and an improved lever press with three weights (1,500 kg each) indicate the «technological revolution» of the Hellenistic period (Kloner and Sagiv 1994). The description of this press by Heron of Alexandria includes the beam (supported by two piers) anchoring into a niche but not the pulley unit. The peak of oil production was no doubt during the Byzantine period (4-7th century AD). The geographical distribution of olive cultivation covered the whole of the Mediterranean area, even some semi-arid and arid regions. The introduction of new techniques, such as the screw in the Roman period, made it possible to multiply the capacity of oil mills which generally included two presses and one mill. The social and political structure dictated that most of the presses were owned by the private sector (Mishna Baba Batra 10.7). In many villages 5 to 7 large presses functioned simultaneously (Frankel 1989) and many more in towns. Only a minority of the oil mills was owned by monasteries (Kh. Loya, the city of Kh. Karkara) or big estates (such as the one close to Ashkelon). Conservatism (meaning the use of techniques over long periods) combined with regional diversity produced a huge variety of installations. These differences were dictated by internal and overseas connections and the course of political events in each region. In areas like southern Phoenicia (Upper Galilee), Samaria and Judaea that were characterised by a deep-rooted rural population, changes were slow to come about. The improved beam-press was confined to Upper Galilee with its two stones (*arbores*) anchoring the beam and the press bed (*ara*). Both devices were introduced by Cato the Elder (who had apparently seen oil presses in Carthage) and were mentioned in Jewish literature as the *betulot* and *memel* (Ma'aserot 1:7, Baba Batra 67.72). The *ara* drained into two barrel-shaped containers – one collecting-vessel and one separator (*yamim* – Tosefta, Ma'aser Richon 1:7) (Avi Yona 1945). The southern Judaean beam press was followed in the Byzantine period by a direct screw press, both usually keeping the IA II central draining system. The Golan was inhabitated by Jews from Judaea in the fourth century AD and the presses in the 100 oil mills there which were of the southern type quickly adopted the northern method with direct screw presses. Jerusalem, the cosmopolitan metropolis, had a variety of devices from all over the ancient world. The Roman installations in Italy and the Aegean were certainly influenced through North Africa by the presses of Phoenicia (Frankel et al., forthcoming).

During the rule of the Umayides and the Abbasides (11-7th century BC), the centre of olive cultivation (technologically unchanged) moved south to

Samaria and Judaea and the Gaza Coast region. The exploitation of the country during the Middle Ages caused great deterioration in the economy and thus also in olive production and missed out on the pre-industrial inventions of Europe such as the cogwheel device. Symptomatic of this decline is the large-scale export to Europe of alkali (as raw material and not the final product) for the soap and fine glass industries during the 15th century AD. This alkali contains sodium carbonate that could only be produced from the ashes of halophytic plants growing in such regions, whereas European plants contain potassium (Loewenstein, forthcoming). The *borit* (Jer.2:22) could either be the alkali itself or a liquid mixed with oil – the first «liquid soap».

Olive oil was a basic element of daily life with the fruit and its oil being major constituents of the diet. Olive oil seems to have been used predominantly for religious purposes as revealed by the descriptions of ritual offerings in the Bible and as indicated in the Mishnah, the Talmud and later documents (Ibn Faqiah al-Hamaani: 92,2,10). A typical meal (5 different cooked or uncooked dishes –Lev.**2**:4) contained grain or flour mixed or rubbed with oil in a proportion of 3:1 (Ezekiel **45**.14), sometimes with added honey (Ezekiel **6**.13). But the favourite cakes of Roman times were the *vatica* which contained only flour, salt and oil. Meat was generously oiled before and after cooking (Mishnah Pesachim 7:3; Num.**15**:1-16). Olive oil was added to drinks like *hilmi* (Mishnah Shabat 14:2), *alontit* (Tosefta Shabat 15:17) and *anigron* wine (Mishnah Berahot 33:72). Therefore the yearly amount of one *log* – 0.5 litres – per person (Mishnah Ketubot 5:8) seems to have been an exception. An amount of about 20 litres would seem to be more likely. Oil was used as a main source of light (Mishnah Shabat 23:71). Olive residue was much prized as fuel (Mishnah Damai 1,3). Anointment was a daily act (I Sam 12.20), and usually every part of the body was oiled. The more affluent people poured it over their heads and beards (Ps.**133**.2), bathed their feet in it or were massaged with oil while lying on a marble slab. The oil was provided by the *oliyar* (*oleries*) who served in the public Roman baths (Tosefta Shabat 6:14). Olive oil also served as a base for perfumes and cosmetics. The perfumiers were highly qualified professionals (Neh.**3**.8, I Sam **8**.13), the biblical *rokkhim* or *mefatmin* in the Hellenistic and Roman periods (Tosefta Shvi'it 6:13). Perfumes were costly and were kept with other treasures (II Kings **20**.13). They were manufactured by steeping (mainly hot steeping or maceration) various parts of fifteen plants: balsam, myrrh, spikenard and others. Only a few of these plants were grown in Israel in oases such as Ein Gedi (Sol.**1**.14), where a perfume workshop from the 7th-6th century BC has been excavated, or in the Gilead. Most of them were brought from distant lands such as India. The great economic importance of the perfume industry of Ein Gedi during the Roman period is evident from the fight over the plantations between Titus and the Jewish rebels in AD 70 (Pliny, *Nat. Hist.* XII). Olive oil was a well-known remedy for sore throats and cuts and bruises (Tosefta Shalbat 10:12). It was a main component of worship in shrines and temples during the biblical period (Winefeld 1994, Stager and Wolf 1981). Olive oil was used from an early stage for anointing kings and for libation of holy objects (I Sam **10**.1). It goes without saying that the name *mashiah* – Messiah – means «the anointed one» (John **12**.3). In the First and Second Temple in Jerusalem, pure oil lit the everlasting candle and the Holy Lamp, or *menorah*, with its seven branches (Ex. **27**.20, **25**.37). Lamps with 5, 6 or 8 branches were frequently used in the numerous synagogues that were built in the Roman and Byzantine periods.

The 8-day hanukah festival was celebrated for the first time by Judah the Hashmonai in commemoration of the Temple's recapture in 164 BC. The lighting of the hanukiah, a special lamp with eight branches, became one of the most important religious precepts during the Middle Ages when the Jewish communities were oppressed and scattered by the diaspora. When Jews finally returned to Israel at the end of the nineteenth century, the holiday took on Zionist connotations of national liberation. The state of Israel embraced the olive tree as the symbol of peace by decorating its badge with the menorah with an olive branch on either side.

Centenarian olives of many species are still flourishing today in Israel and may descend from those that were common in ancient times – the most common being suri (25-38% excellent oil), melisi (22-16% fine oil) and nabali (28-22% good oil). In Roman times these were identified as gadol, katan and beinoni – large, small and medium-sized (Kislev, 1994). The similarity between the traditional methods that are still widely used and ancient methods points to the decline of olive cultivation over the last one thousand years. Olive cultivation in Israel today is spread over about 38,000 acres, with 175,000 acres in the West Bank. Israeli agriculturalists and consumers have recently been showing increasing interest in olive growing and oil processing.

TRADE IN OLIVE OIL

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THE TRANSPORT OF AMPHORAE BY SEA, AS DEPICTED ON ROMAN MOSAICS

The Termi di Nettuno in Ostia in Italy are decorated with a mosaic floor dating from AD 132-139 that depicts pygmies in black and white and a ship loaded with amphorae, two of which recline at an angle in the prow of the ship while a third is shown standing upright[1]. The same motif is repeated in a painting in Pompeii[2] and also in the Neptune mosaic in Merida, Spain. The latter was designed at the end of the second century by Seleucus and Anthus[3]. It depicts a pygmy towing a vessel laden with three round amphorae, two of them with handles.

A well-known mosaic can be seen in the «Foro della Corporazione» in Ostia, Italy[4]. This shows a slave dressed in a short tunic and carrying an amphora on his shoulders from one ship to another. To the left is a merchant ship equipped with a mast but no sail. The second ship has a pointed prow. It too has a mast but no sail. There is a gangway uniting both. This mosaic dates from AD 190 to 200. The unloading of amphorae containing wine or oil is also shown on the Torlonia relief which dates from the time of Antoninus[5].

At the same place in Ostia (Stationes 51-52), two more ships loaded with amphorae are depicted on mosaics. On one of them, the vessel has two rudders held by a helmsman dressed in a tunic and seated in the stern of the ship. In the prow there is a cabin supported by four pillars, the typical *cabura*. The prow is at a slant and on the bridge a number of round, short-necked amphorae with two handles are shown. Also shown are the rigging and the mast. The second vessel, also a merchant vessel, has a cabin and two rudders but no helmsman. The centre of the vessel is laden with amphorae which, like those already mentioned, seem to be of the Dressel 20 type which means they probably came from Hispania. The date assigned to both mosaics is the same as that for the previous one, namely AD 190-200[6].

Ships laden with amphorae are also depicted on African mosaics. Thus, for example, on the mosaic in Carthage entitled the Triumph of Venus, which dates from the end of the fourth century or the beginning of the fifth, we see three cupids, two of them fishing, while a third is seated holding a circular recipient with a neck which may well be an amphora[7]. The famous Althiburus mosaic in the House of the Muses, dating from the second half of the third century, shows what amounts to a catalogue of various types of ship[8], including one with a pointed prow transporting amphorae placed at an angle[9].

A third mosaic depicting a ship laden with amphorae was discovered in the Tebessa Thermae and dates from the start of the fourth century. The whole of the ship's central area is loaded with amphorae. The ship is equipped with oars, a cabin, a mast and a sail and bears the inscription *Fortuna Redux*[10].

In the Archaeological Museum in Apamea, Syria, we have seen two small mosaics decorated with two boat-shaped vessels carrying amphorae.

Two other Hispanic mosaics show merchant vessels although they are not carrying amphorae – the Toledo mosaic floor in which one ship has on deck a container which may very well be an amphora, and one from Cencelles, Tarragona, dating from the middle of the fourth century[11].

Scenes showing merchant vessels laden with amphorae are rare on Spanish mosaics, despite the intense trade in food products between Spain and Italy, which is well documented by findings on the seabed[12]. On a stele found in Tortosa, which in ancient times was called Dertosa, there is an engraving of a *navis oneraria*, a corvette-type vessel equipped with a mast, a square sail, two rudders in the stern and a small sail at the prow, about 400 displacement tons. This ship probably has some type of funerary significance. It may refer to the voyage by the soul to the islands of the blessed or to the profession of Caecilius who was a *cubicularius*. The same meaning attaches to the merchant ship on a mosaic on the Isola Sacra di Ostia dating from the second half of the third century. On the Ostia mosaics there are numerous representations of unladen merchant ships, such as those in the Foro della Corporazione (Stationes 49, 3, 19, 49, 18, 15, 21, 10, 23, 46, 47, 45, 32). Some of the inscriptions indicate to whom the vessels belonged: *navicularii bignarii, naviculari turricitani, navicularii kartha(ginenses), navicularii et negotiantes, navicularii miscienses*. The last-mentioned city is situated east of Carthage. The *navicularii et negotiantes karalitani* came from a city that used to be called Carales and today is Cagliari in Sardinia. The *navicularii syllectini* came from Sillectum in Byzacena and, finally, the *navicularii narbonenses* dating from 190-200 BC.

It seems surprising that, although Hispania exported large quantities of oil, salt fish and minerals to Rome via Ostia (Str. 3,2,6), there is no statio hispana in Ostia.

THE LATEST WORK ON THE EXPORT OF BAETICAN OLIVE OIL TO ROME AND THE ARMY

José M. Blázquez

Over the last few years, much work has been carried out on the export of olive oil from the province of Baetica to both Rome itself and the rest of the Roman Empire. The key for understanding the export traffic to Rome[1] is the material from the Monte Testaccio in Rome, which is almost completely composed of amphorae from Baetica dating from the Imperial period.

The aim which the team excavating the Monte Testaccio set itself was to understand the most important destination of Baetican olive oil, the city of Rome, in the belief that such an understanding would throw much light on the problems concerning the export of Spanish olive oil not just to Rome, but also to the rest of the Roman Empire. It is in fact found not only in the European provinces of the Empire but also in Africa and especially Mauritania Tingitana[2], an area which itself produced olive oil, as is shown by the large number of oil presses to be found in the capital of the province, Volubilis. The number of amphorae stamps of Baetican origin is enormous[3]. In Alexandria alone[4] around 1,000 stamps with the names of Spanish olive oil producers have been found. Various others have recently come to light in Israel.

OLIVE OIL FROM BAETICA IN GERMANIA

The sites which imported Baetican olive oil in Germania were above all military camps and the town of Cologne. The provision of olive oil from Baetica, supplied in Dressel 20 amphorae, to these centres was probably on a regular basis, although at the moment not all military camps provide us with the same information. At Nimegen[5], for example, a large number of stamps from Baetican amphorae dating from the periods of the Flavian emperors and Trajan have been found. It is likely that a similar pattern would also have been true of Britain.

The export of Baetican olive oil to Germania reached its high point in the Antonine period, particularly between the years AD 141-161. In the final half of the second century, these exports decreased in volume, due either to the Moorish invasion of Baetica or the wars against the Quadi and Marcomani. However, this decline is not consistently found at all importing sites and two of the sites where Spanish oil was produced, Canama and La Catria, increased their exports in this period.

The major exporting centre of Baetican olive oil during the Flavian and Trajanic period was beyond doubt Catria (Lora del Río, Seville), which was the principal exporter for the *annona*. From the middle of the second century onwards, these exports decreased in volume, recovering in the first half of the third century. In the area neighbouring La Catria, on the other hand, while the export of olive oil was of importance in the Flavian and Trajanic periods, it dropped in the middle of the second century and had almost vanished by the third. Some *figlina*, pottery workshops, at La Catria were probably confiscated by Septimius Severus (SHA, Vita Sev. 12). In the town there was an intervention warehouse for the supply of olive oil to Rome and the army, as the use of the word *portus* found on its amphorae shows.

The *Municipium Flavium Arvense* only became important as a centre for the export of olive oil in the third century A.D. An inscription from the first half of the second century (CIL II.1064) shows that its land was parcelled out amongst small landowners or tenants working in this trade, whose patron was called Fulvius Carisianus. Malpica and its neighbourhood only exported Dressel 20 amphorae in large numbers in the middle of the second century A.D.; they disappeared in the following century. The *Municipium Flavium* of Canama (Alcolea del Rio, Seville) also exported a large amount of olive oil to the *limes*. Inscriptions found on amphorae stamps here appear to show that several *conductores vectigalium* were present in Canama, an interesting fact for our knowledge of important aspects of the Roman administration in Baetica. In the mid-second century AD this town exported a large amount of olive oil to Germania but stopped doing so in the third century. The area of Astigi (Ecija, Seville) only became important as an exporter of olive oil in the third century A.D.; more specifically, the site of Las Delicias exported olive oil to Germania from the Flavian-Antonine period, but these exports reached a large scale in the third century.

From this information we can conclude that there was a link between various olive oil producing centres in Baetica and some German sites. Each exporting area had its period of importance and the trade was in the hands of a particular group of individuals or families who had connections with the *annona* in a private capacity.

Various calculations have been made of the volume of the exported olive oil. It has been estimated that each legion, some 6,000 men, would have required around 1,370 amphorae a year; a Dressel 20 amphora has a capacity of 210 pounds, leading to a figure of 288,000 pounds of oil per annum. Each olive tree in Baetica therefore would have produced some 20 pounds of oil a year. It has been generally accepted that olive oil from Baetica was exported to Germania along the Rhône. Remesal, on the other hand, believes that it was exported by an Atlantic route, owing to the difficulties of navigation on the Rhône and of taking the amphorae overland to Germany. The Roman lighthouse at Corunna was built to help this trade[6]. Pliny (NH 2,167) and other authors allude to this maritime traffic. Wrecks of ships carrying Dressel 20 amphorae from Baetica have been found on the Atlantic coast of Galicia[7].

Remesal's study also provides other important information about the function of the *annona militaris*. It calls attention to the fact that there was no specific title given to this branch of administration. Augustus created an efficient administrative structure, the *praefectus annonae* of Rome, with an *officium* which centralised the tasks of collection and distribution using employees in the provinces, the *procuratores Augusti*, who were given the task of obtaining the produce. In this task they relied on the help of the troops who were under the *officium* of the governor of the province. This system became progressively more complicated.

In regard to the organisation of the system of provisioning within the army itself, Remesal only concerns himself with the supply of olive oil from Baetica under state control. He believes, following D. van Derchem, that there was no central office dealing with military supplies, but that this function was part of the task of the *praefectura annonae*. From the Claudian or Neronian period onwards, a number of inscriptions (CIL Vi.8538, 8540, 8539, 8541, etc.) refer to low-ranking personnel concerned with provisioning the army who were probably employed by the *praefectura annonae*.

The Roman state would have been able to obtain olive oil, in the same way as other products it needed, through the *fiscus*, in the form of *donationes*, payments effected through *procuratores*, or by requisition through the so-called, and feared, *indictiones*. The control exercised by the *fiscus* over the Baetican olive oil trade was minimal in AD 41. However, by AD 71 it was almost total as the Monte Testaccio shows it was in the Antonine period. Therefore a rigid form of control over this trade was established by the Roman state between AD 41 and 71. Perhaps it was Vespasian who increased the amount of control. The first *procurator frumenti comprandi*, M. Arruntius Claudianus, who possibly organised the supply of Rome and the army from the capital itself, dates from the reign of Domitian[8].

From the information gathered by Remesal it is clear that the Roman army on the Rhine had sufficient stocks of Baetican olive oil to supply other units of the army and that the armies were supplied with olive oil from Gaul and Spain by the Rhône and Atlantic.

A well-known inscription from Hispalis (Seville) (CIL II.1180) mentions an Ulpius Saturninus Possessor, a *praefectus annonae ad oleum afrum et hispanum recensendum*, from the reigns of Marcus Aurelius and Lucius Verus. Contrary to the interpretation usual, which is that his post was a provincial one, this title probably proves that Possessor's duties were located in the *praefectura annonae* in Rome and that his brief was to oversee the import of olive oil from Baetica and Africa, and the transport of other products for the *annona*, paying the transport costs which the *navicularii* presented to the *annona*. Possessor probably held his post at the beginning of the wars against the Marcomani. At this time a *subpraefectura annonae* was created, a post which was held by P. Cominus Clemens from AD 170. The *praefectura annonae* would have taken care of the provisioning of Rome and the army. The inscription of Possessor also tells us that the *vecturae* were the price of transporting the goods and that there was no trade as such between the *navicularii* and the *annona*. Instead there merely existed traffic in the goods needed. Within the Empire, commerce was largely in the hands of the *annona*. Therefore the reign of Marcus Aurelius saw the development of the organisation of the *annona*, along the lines which had been laid down in the Flavian period. Under the Severan dynasty the *annona* underwent further changes.

The stamps from the Dressel 20 amphorae allow us to see that three workshops and their estates were confiscated by the Imperial authorities at this time and administered by them. On the death of Caracalla these estates passed from the imperial *ratio privata* to the *patrimonium*; Alexander Severus made them private property. This evolution can be seen from the *tituli picti* on Baetican Dressel 20 amphorae. It appears that Septimius Severus enriched his *ratio privata* at the expense of the *fiscus*, which had received them as *patrimonium principis* and that he allowed the *ratio privata* to monopolise the trade for the *annona*, to solve the problem of the rising cost of maintaining the army, and at the same time to maintain a monopoly over the exactions of the *fiscus* which had previously been carried out by *publicani* or *conductores*. Alexander Severus' great contribution was to liberate the trade in the *annona* once more, allowing private individuals to transport goods pertaining to it again. The Monte Testaccio ceased to be added to in the reign of Gallienus, and therefore our evidence too stops at this time. Dressel 20 amphorae now disappear and other forms of amphorae take their place, e.g. the Dressel 23 form. These changes may be connected with military reforms.

This theory is extremely radical, as normally it is believed that after the end of the Monte Testaccio in AD 257, Spain stopped exporting olive oil to Rome and the army on the limes. This hypothesis would find strong support in the fact that there are no Dressel 20 amphorae in the underwater finds from the Spanish coast[9] and that there were a large number of African amphorae in Spain in the Late Empire, clear evidence of the import of African olive oil[10]. Remesal's theory is supported by the fact that Spanish Dressel 23 amphorae are found built into the vaults of the Circus of Maxentius in Rome[11], that the vaults of the mid-fourth century church of St. Gereon in Cologne are reinforced with 1,200 Dressel 23 amphorae[12], and that Dressel 23 amphorae dating from the first half of the third century have been found in Ostia. Dressel 23 amphorae have appeared in Spain at Ampurias (dating from the first half of the third century) and Tarragona (dating from the first half of the fifth century), and were manufactured in Baetica, where workshops which produced Dressel 23 amphorae have been found at El Tejadillo (Alcolea del Río)[13].

It can also be deduced from the study of the Spanish amphorae found in Germany that there was an extremely close interprovincial dependency between those areas which produced olive oil and those which imported it, and a large amount of state intervention. On the limes of Britain and Germany very little evidence for African olive oil has been found. Contrary to what has been supposed, therefore, there was no *annona militaris* but merely a *praefectura annonae*. Another important conclusion of Remesal's study is that the officials in charge of the supply of the army in wartime belonged to the *ordo equester*. During the Early Empire there was a controlled market which the state destroyed to take control of the means of production itself. The fundamental economic relation in the trade was that between Baetica and Rome, Rome being the centre of the imperial administration, not that between Germany and Baetica. In the reign of Diocletian the emphasis of trade from Baetica changed radically and was orientated towards the army and the officials of the Roman West.

THE ECONOMICS OF OLIVE OIL: ANCIENT TIMES

J. Remesal Rodríguez

The olive is a tree that in the wild state is to be found all over the Mediterranean Basin. It does not bear heavy crops and the fruit, which has a bitter taste, gives oil which is also bitter. However, in the most distant past man learned to cultivate the tree and obtain from it a highly esteemed fruit, the olive, and from it an oil that is useful not only as food but also for numerous other purposes.

We have very few documents to go on concerning olive tree cultivation techniques and the extraction of oil in ancient times. It was only in Roman times that works on agriculture were written and these go into such aspects in detail. Archaeology, however, has taught us that techniques known to man in Roman times had been known for a long time before that. These same techniques can be said to have survived to the present day, only being replaced by recent innovations in agriculture and new technology for crushing olives, beginning with the hydraulic press which replaced the weighted beam press that had been in use for thousands of years.

The economics of olive-growing and production of oil in the ancient world should be studied from two different aspects – the society's own needs and its capacity for producing surpluses for export. To a large extent such capacity was governed in turn by the existence, or absence, of easy means of transport and this factor characterised the economy of the ancients to a large degree.

On the first aspect, own consumption, we have hardly any information at all. We can assume that, from very ancient times, the inhabitants of the shores of the Mediterranean took advantage of everything the olive tree had to offer, in addition to its fruits and oil. For example, other by-products such as the branches and foliage of the olive tree could be fed to cattle or woven into baskets and olive pomace was useful as a fuel or, together with vegetable water, as fertilizer. Olive wood was also useful, being both hard and beautiful.

With respect to a capacity for producing and marketing surpluses, we are somewhat better informed. This obviously required previous knowledge of production techniques, production in excess of local demand and the existence of large plantations.

The first references we have show that the Syrian and Palestinian region was where the production and marketing of olive oil first got under way. Recent findings in the ancient city of Ebla, close to the modern city of Aleppo in northern Syria, and consultation of its archives teach us that halfway through the third millenium BC olive orchards already came third in terms of crop acreage. Documents dating from about 2500 BC, describe how fields were demarcated by counting the number of olive trees standing in each one. One of these documents mentions the existence of three fields, two with five hundred and one with one thousand olive trees. Another document talks about the different varieties of olive oil and, for the first time, mentions exports of high-quality olive oil to other kingdoms.

About halfway through the second millenium BC, reports mentioning olive oil suddenly become much more numerous and references have been found in the city archives of Alalakh, Mari and Ugarit. In many of these documents olive oil is mentioned as a medicine but in others, for example in the Mari documents, we are told of imports of olive oil from the city of Aleppo (close to the ancient city of Ebla from which we have documents that go back in time another thousand years). The Mari documents show that the price of olive oil was five times higher than that of wine and two and a half times more expensive than seed oils (sesame or linseed). These documents are an indication of the relative value of olive oil. What we cannot determine is whether this difference occurs solely on account of different production costs, or whether considerations of prestige or scarcity are also involved.

An ancient Syrian document dating back to the start of the second millenium BC from Karum in Kanish, a Syrian trading centre situated in Hittite territory in central Anatolia, tells us of a local merchant's order of first-class olive oil from the capital Assur or, alternatively, Hahlum. (This latter place has not yet been identified but it was either on the Upper Euphrates, in Cilicia or in northern Syria). This makes it clear that olive oil was traded over long distances. Documents from the Ugarit city archives dating from the thirteenth century BC prove that olive-growing was important, although it took second place to vine-growing. Documents have been preserved which show that olive oil was used to pay tax to the Palace and, at the same time, there are indications that the Palace itself paid for certain services in olive oil. However, perhaps the most important document is one which describes the trade in olive oil between Ugarit and Cyprus and Egypt.

We have very little information about olive oil in the Egypt of the Pharaohs. The first indication is in a relief from the 18th Dynasty, i.e. 1570-1345 BC. The Pharaoh Ramses III (1197-1165 BC) encouraged the cultivation of olive trees. Sources from Greek and Roman times, which is when olive trees were cultivated most widely, indicate the existence of olive orchards in Thebaid to the south of the country, in Alexandria and, above all, in the Fayum oasis. These same sources go on to say that Egyptian olive oil was of poor quality and had a strong smell.

We are better informed about the production of olive oil in the Mycenaean world. Documents written in Linear B and dating from some time during the thirteenth century BC indicate that on Crete oil from both wild trees and cultivated olive trees was used. It is said that in the western wing of the palace at Knossos up to 250,000 litres of olive oil could be stored, although other research has reduced this figure to one third of that amount. It has been calculated that the stores of the palace of Mallia could hold up to 23,000 litres of olive oil. Consignments of more than 10,000 litres sent from rural areas to the palace at Knossos are recorded on tablets. It has been suggested that oil from wild olive trees was used as a base for perfume.

There is a good deal of archaeological information about the development of olive cultivation in the Syrian and Palestine region at the beginning of the first millenium BC. Excavations in Israel have found the remains of many olive oil presses and have shown the techniques developed for obtaining oil, such as circular millstones and beam presses in which stones were used as counterweights. Passages in the Bible also confirm the importance of the olive oil industry.

The expansion in the use of olive oil throughout the Western Mediterranean is attributed to the Phoenicians, who took it with them to northern Africa and southern Spain at the beginning of the first millenium, and the Greeks who took it to Italy. Trade contacts between the two ends of the Mediterranean began to flourish around that time, with many of the goods traded being food products, olive oil taking pride of place.

Although Classical Greek literature includes many references to the use of olive oil, there is little mention of the methods of production and marketing of both olives and olive oil. The myth featuring the goddess Athena who gave the Athenians the olive tree and taught them how to put it to good use, is a clear indication of the expansion and importance of olive tree cultivation in Attica. According to Solon's Laws, olive oil was the only food product that could be exported from Athens. This demonstrates the importance of olive groves in Attica, not only as a key element of land occupation and employment but also, and above all, because of its trade value. By exporting its olive oil, Athens was able to obtain the grain it lacked.

The expansion of olive cultivation in the Italian Peninsula was slow and depended to a large extent upon the social conditions brought by the Roman conquest of Italy. The most highly-prized Italian oil was from Venafro in Campania, although the area where most oil was produced was Magna Graecia, one of the first areas of cultivation.

The creation of the Roman Empire laid the foundations for the development of a much more open economic system than had existed hitherto. The peace which Augustus instituted throughout the Mediterranean facilitated travel for commercial purposes. Rome, the creator of this Empire, enjoyed the fruits of her exploitation of the resources of all the countries she dominated. Augustus based his political power on two fundamental pillars, the plebeian inhabitants of Rome and the army. He had to provide for both: the army because it depended on him economically, and the people of Rome because they were happy to submit politically to the hand that fed them. So Augustus created an economic system in which each province of the Empire satisfied Rome's interests and supplied the army with the products it was able to produce.

Documents show that it was Baetica, today called Andalusia, that was the first province to supply olive oil as from halfway through the second century onwards and that North Africa was keen competition for the Andalusian olive oil. We are relatively well-informed about olive oil production and trade in Andalusia during the Roman Empire and what we know is an essential point of reference for studies on olive oil in ancient times.

Andalusian olive oil was distributed all over the Roman Empire –from Britain to Egypt – in amphorae, the production centres of which were located in a triangle formed by the cities of Seville, Cordova and Ecija. The identification of these centres of production has made it possible to determine that the ancient city of Axati (today Llora del Rio, Seville) was the region with the highest level of production. A host of details were noted down on the amphorae in which the oil was exported – the empty weight of the amphora, the net weight of its oil content and the name of the trader or carrier, together with a complex system of fiscal checks and the date when the transaction took place as registered by the consular authorities. In Rome, when amphorae containing Andalusian olive oil were empty, they were thrown onto a tip which was given the name Monte Testaccio. Millions of Andalusian amphorae were dumped there and many of the inscriptions on them have been preserved. In this way what was in its day a rubbish tip constitutes for us a vast archive and the data found in it has enabled us to revise many of our theories and hypotheses about the economic organisation of the Roman world.

THE ECONOMICS OF OLIVE OIL: THE MIDDLE AGES

GEORGES COMET

The medieval history of the olive is not yet well known because local situations vary greatly and it is impossible to draw up a synthesis until careful regional studies have been carried out. However, we can speak of the medieval olive in historical terms and raise certain questions[17,18,2]. Olives and olive oil were certainly consumed and sold during medieval times but little is known of planting methods, varieties, cultivation techniques, processing and equipment. Moreover, trends in olive growing over the whole period are not clear. Three examples can be taken – Provence, Al-Andalus and Italy.

La Provence was not an olive-growing area in the Middle Ages, only as from the sixteenth century. Carpological studies shed doubt on the presence of olives[19] which are mentioned only rarely in texts before the mid-fifteenth century. The first mentions appear in the eleventh and twelfth centuries (Draguigna, Marseilles, Nice). In the thirteenth century toll tariffs show that olive oil was being transported. In the fourteenth and fifteenth centuries, a time of economic depression, there is more information[15,21,6]. However, it would be simplistic to assume that olive cultivation took off as a result of the crisis.

Olive orchards were important in certain regions (El Condado, the coast) but in others were non-existent. In the fifteenth century, Jews came to be the main traders in olive oil[11] although they owned neither orchards nor mills.

The situation in Spain was very different[4,22]. In the eleventh century the olive became part of the Islamic world. Al-Andalus and especially the region around Seville were great producers and exporters of olive oil: «The people of Seville are said to be very rich. Their main trading commodity is oil which they send far away by sea both eastwards and westwards» (Ibn Nadhdhim).

In the twelfth century, Andalusian oil was exported to Alexandria. The main centres of oil production were Seville, Cordoba, Jaen, Valencia, Badajoz, Coimbra, etc. Sevillian olives were said to keep for twenty years and their oil never to go rancid. In the tenth century, Al-Razi said that production was such that, if the oil were not exported, the inhabitants of Seville would not be able to store it.

In Italy, several zones must be distinguished[10]. In the north, olives were grown even in areas where they had not existed during ancient times, probably because Rome preferred to import it from regions where olive cultivation was more profitable, such as Istria[14,16]. The olive orchards were small in size, and texts often mention gifts of some ten trees or so for the lighting of a church. This would suggest that oil usage was limited although such a view may be biased by church documentation.

In central Italy, olives sometimes grew in the middle of sown fields or vineyards until the fifteenth century when intensive cultivation began around Lucca, Siena and Florence. The Florence cadaster showed intensification which was to increase in the sixteenth century and, as soon as families achieved a certain degree of welfare, they started to produce their own oil.

In southern Italy, Gaeta was a major port for the olive oil trade and Apulia was an important trading centre as from the thirteenth century. The situation round Palermo in Sicily is well known: vast olive orchards around the town were grouped into a capitalist trading organisation to satisfy the high local demand[5]. Sicily therefore consumed more than it produced and had to import. In all, oil remained a marginal industry throughout the Upper Middle Ages, and the olive tree was relatively rare in the Italian peninsula as late as the fourteenth century, except around Gaeta and in Apulia. In the rest of Italy, development was to take place in the fifteenth century and the changes that were to shape today's landscape in central Italy occurred from the sixteenth to the eighteenth centuries.

We know little about the techniques used in Italy. Very sophisticated techniques with grafting, irrigation, etc., were used in southern Italy and, if certain authors are to be belived, the trees of medieval Apulia had sprouted from ancient stocks[12]. On the other hand, the writings on Andalusian agriculture are very informative[12]: tilling with spades, weeding between rows, plantation in rows running north to south so that the winds from the east and west could pass without difficulty, nursery propagation, seedbeds, cuttings or rootstock cuttings, layering, grafting, transplantation after three years in the nursery, irrigation in the nursery. All these techniques had developed from a long tradition of extremely meticulous irrigated cultivation.

As regards pressing, in 1984 an analysis was carried out[1]. We know from a few texts that both screw and beam presses were in use in Provence at the end of the Middle Ages. No presses remain from that time in Provence but press sites have been found by archaeologists. An eleventh century oil mill in Cadrix is the oldest example found so far[7,8]. The site is a high fortified enclosure probably used for both military and economic purposes such as tax collection but the rustic nature of the equipment shows that production was by no means centralised. During the summer of 1991, a new medieval oil mill was discovered near Forcalquier. It is still being studied.

One matter remains to be determined. What was the oil used for?

We know of certain industrial uses – for soap and for textile treatments. There were also pharmaceutical uses – oils of rose, violet, laurel. Religious buildings were lit with oil lamps and small amounts were used for liturgical purposes. The use of oil in cooking, however, is not clear.

Recipes dating from the fourteenth and fifteenth centuries show that olive oil was rarely used[9]. It seems to have been considered basically a vegetable oil that was authorised for times of abstinence – Fridays, the eve of religious festivals and lent. It can therefore be assumed that animal fats were preferred. It is reasonable to doubt whether in Provence in the Lower Middle Ages olive oil was really used outside lent and apart from frying fish[20]. It had to compete with walnut oil and lard. Later, towards the end of the Middle Ages, little fat was used for cooking and most sauces were made with no fat at all. This would explain the low consumption of oil in a producer region such as Provence.

With respect to production, trends varied from one region to another. In Provence, archaeological remains seem to indicate that large amounts of oil were produced in ancient times, with much less in the Upper Middle Ages. Production began to increase as from the thirteenth century, growing especially fast in the seventeenth century. The situation in Andalusia was very different. Here growth was continuous, making this the main Mediterranean centre for production and exports. On the subject of Italy, writers do not agree. Some consider that olives in Sabina played the same essential role in the medieval landscape as under the Romans[6]; others consider that, if production decreased in the Italian *villae*, this could only have been in the third and fourth centuries as a result of competition from African and Spanish oils. As from the fifth and sixth centuries, production expanded until the eclipse in the tenth and eleventh centuries[13, 6]. The absence of oil production on small farms in the Lucca area in the thirteenth century does not necessarily indicate that the crop had disappeared but only that it was at reduced levels.

In conclusion, it cannot be stated that any general trend existed throughout the Western Mediterranean: developments have to be studied region by region. But the olive economy and the techniques used form part of a social system and cannot be isolated from the social, economic and religious components of life at the time. During the medieval period, even more than at other times, the olive has to be considered as one of the signs and components of the whole social structure.

THE ECONOMICS OF OLIVE OIL: MODERN TIMES

ENRIQUE MARTÍNEZ RUIZ

Possibly the modern period is one of the most important for olive cultivation at least with respect to the northern half of the Mediterranean Basin. This was the time when Spain and Italy and, to a lesser extent, Greece came to dominate as olive growers.

The recovery of trade at the end of the Middle Ages brought about an increase in the land surface given over to olive-growing and in the sixteenth century in Italy olive orchards exceeded those of the Roman Empire although the wealth created by the discovery of America was only noticeable in Spain. The economic crisis in southern Europe during the seventeenth century created problems for the olive. In southern Italy, for example, shortages and disease discouraged olive cultivation which decreased, partly because of a lack of wood which led to olive wood being used to satisfy the demand. This trend was balanced out in other areas which set up orchards, sometimes on sloping or terraced lands. In addition, demand and the facility of trading in olive oil caused a redistribution of the producer areas with the northern marginal lands being gradually abandoned while the Ligurian orchards were promoted. The latter were more difficult to work but were less exposed to harmful weather conditions, especially winter frosts.

Some writers consider that the year 1709 was critical because it was «the turning point between old-fashioned olive growing, with its mythical or religious connotations and its tradition and history, and modern cultivation». The freezing spell in January –the «terrible winter» described in many chronicles – practically banished oil from the market. Prices shot up and this was the opportunity for a small number of families to pave the way for subsequent prosperity by managing to continue trading. New orchards replaced the damaged or destroyed ones and today's distribution of olive cultivation began to take shape.

After the period of recovery came one of scientific interest. In 1788 an award was established for olive cultivation by the Academia Georgofilos in Florence which also commissioned in 1805 a theoretical and practical treatise on the olive, eventually published in 1819. All this led to a period of remarkable growth in the first half of the nineteenth century.

With respect to Spain, the sixteenth-century inhabitants of Castile mostly consumed animal fats, especially pork lard, whereas in Aragon and the Mediterranean areas olive oil was basic to the local diet. These consumption patterns were closely tied up with medical and religious prejudice. For example, in places oil was preferred because it was widely believed that the consumption of butter encouraged leprosy. Such beliefs sometimes reached extremes. Braudel wrote that the Cardinal of Aragon on his travels through Europe around 1516 took with him both a cook and large supplies of olive oil. It was also believed that Moors and Judaizers consumed oil whereas long-established Christians ate pork lard. The priest of the Palacios family complained that the Judaizers «in order to avoid eating lard cooked their meat with oil which made their breath small bad». In the seventeenth century, the Jesuit Padre Montoya «practised mortification by eating dishes cooked with olive oil instead of lard».

Nevertheless, the sixteenth century was a time of growth for olive cultivation both because of the increased demand of a growing population and because their needs became greater as a result of the discovery and colonisation of the New World. In Andalusia prices shot up and between 1511 and 1559 the price of cereals increased by 209% whereas that of oil grew by 297%. Large estates were planted with olives and vines and were mostly tended by Moorish farm workers. From the descriptions of certain travellers and from the Royal levies, it can be deduced that olives occupied large areas of land in Andalusia with some towns producing substantial amounts of oil.

During the seventeenth century, the crisis affected olive orchards which not only decreased in surface area and yield but also lost their skilled farm workers with the expulsion of the Moors from Spain between 1609 and 1614.

In the eighteenth century, the data we possess, collected for the cadaster planned by the Marquis de la Ensenada, show that olive cultivation was by no means in decline but rather that the expansion in the nineteenth century was the culmination of a process that had begun long before, possibly in the middle years of the previous century.

Further inland, during the 16th-century expansion in agriculture, olives tended to be relegated to the worst lands, being grown only to meet local needs. During the eighteenth century, in spite of the growth in population and agriculture, the olive continued to be a secondary crop. Oil traders had a hard time because animal fats continued to be used for cooking, in preference to oil. Olive oil was used for religious purposes and for making soap and this may have been the reason for certain new plantations.

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Chapter 2

BIOLOGY AND PHYSIOLOGY OF THE OLIVE

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BIOLOGY AND PHYSIOLOGY OF THE OLIVE

SHIMON LAVEE

The cultivated olive originated from the eastern part of the Mediterranean basin (Zohari and Spiegel-Roy 1975) and is well adapted to the long, dry summer season of the subtropical climate in this region (Lavee 1992). The high survival potential of the olive is due to a number of morphological developmental adaptations such as special leaf anatomy, sectorial shoot-root relation, environmental root system adaptation and its high morphogenetic regeneration potential. Studies are in progress to identify the specific metabolic pathways involved in the high adaptability of the olive tree to extreme environmental conditions such as drought, salinity, high temperatures and also the degree of resistance of various olive cultivars to low temperatures (Fontanazza and Prezziosi 1969). On the other hand, the species *Olea europaea L.* has the genetic ability to respond to luxury conditions. In relatively warm regions with high rainfall or extensive summer irrigation, large trees with high trunks and rich vegetative growth tend to develop. This would rarely be the case in northern regions with a cooler temperate climate in spite of the summer rains in such regions.

PHOTOGRAPH 1. A typical, fully-developed *O. europaea* var. *oleaster* tree, inflorescence and fruit in Sardinia.

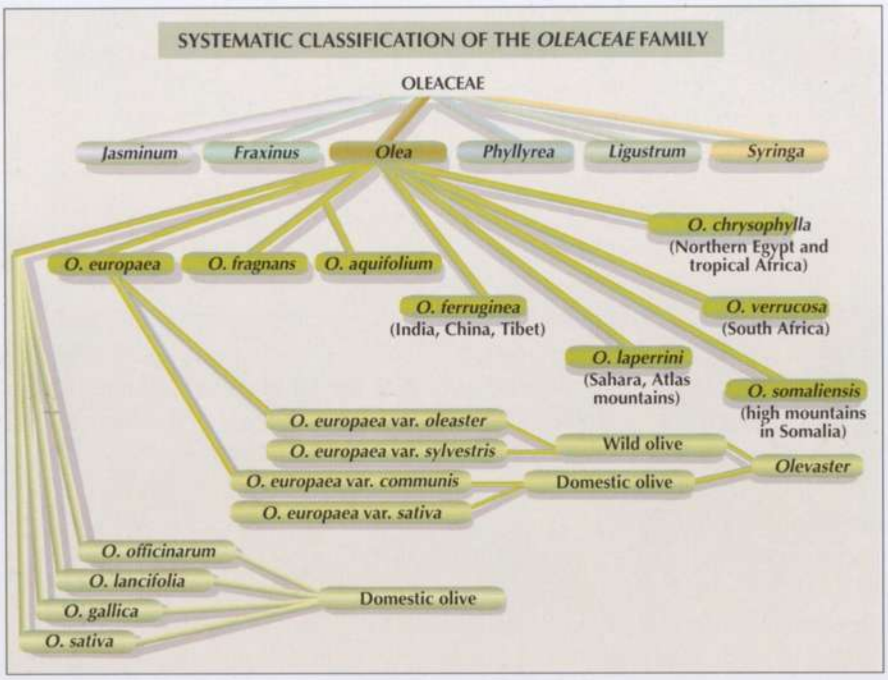
BOTANICAL ORIGIN

The olive belongs to the oleaceae family which contains 20-29 genera according to the classification system (Flahault 1986, Morettini 1972). Various important ornamental plants belong to 4 of these genera – Ligustrum, Syringa, Jasmin, Fraximus. From the three genera Phillirea, Forsythia and Osmanthus only a few plants have been domesticated. The species *Olea* contains various species and sub-species, all of which originate in areas with relatively difficult growing conditions (Zohary 1973). Most of these are shrubs or trees. The only species with edible fruit is the *Olea europaea* to which the cultivated olive belongs. A diagram showing the Oleaceae systematic classification is given in figure 1.

The classification of *Olea europaea* is problematic as different systems have been used (Morettini 1972, Mazzolani G. and Altamura Betti 1977-1981). Originally the *Olea europaea* was divided into two major groups. *O. europaea* var. *sylvestris* and *O. europaea* var. *sativa*. The first included all types designated as wild olives while the second referred to all domesticated olives. The domesticated olives are also referred to as *O. europaea* var. communis and the wild type as *O. europaea* var. *oleaster*. The name Olevaster is also widely used and it refers to domesticated escapes (Turrill 1951).

The wild olive or oleaster usually refers to shrubs or trees with short branches, succulent small round or slightly elongated leaves and small, usually round fruit with a relatively large stone (photograph 1).

FIGURE 2. General botanical classification of the olive family (Oleaceae).



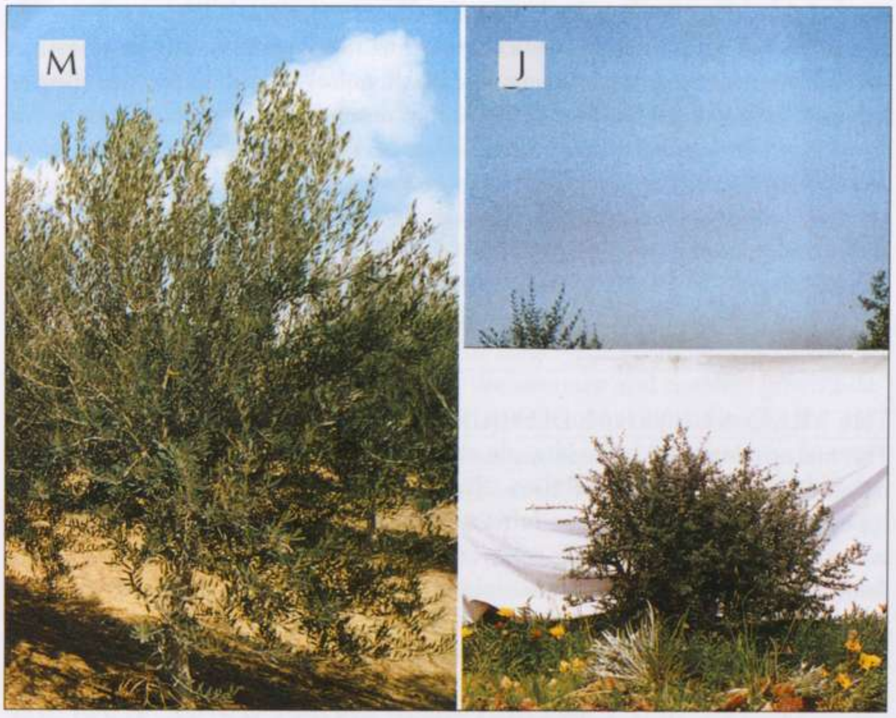
Although the domesticated olive originated in the eastern Mediterranean, Oleaster plants were mostly found further to the west (Greece, Italy). In many cases, Olevaster types grown in heavily grazed areas were mistaken for Oleaster (photograph 2). These trees, due to constant grazing, are kept in their juvenile form with small leaves and therefore do not develop the typical mature leaves of the *O. europaea* species. Such types can easily be distinguished from the Oleaster as they are strictly vegetative and will never flower. When these plants are allowed to grow freely without grafting or simulated intervention, they develop eventually into fruiting trees with regular leaf shape and size as the domestic olive of the *O. europaea var. communis* (photograph 3).

There is still some doubt whether the Oleaster is the true wild type of the domestic olive or an independent subspecies while the true wild olive is morphologically undistinguishable from the present 'domestic' olive. Furthermore archeobotanical studies (Liphschitz et al. 1991) concluded that the relics of olive trees dating back more than 4000 years are undistinguishable from the present domestic olive. Thus cultural escapes as well as the Olevaster are often referred to as wild olives. It was also suggested that the different forms of «wild» olive trees are ecomorphological forms of locally-developed populations, all of which could be considered as *Olea europaea* var. *oleaster* (Lavee 1990).

It is most common today to refer to all cultivated olives as *O. europaea* var. *communis* with some sub-divisions based on leaf and fruit form. According to another classification, these groups are considered separate species and designated as *O. gallica*, *O. officinarum*, *O. lancifolia* and *O. sativa* (Ciferri et al. 1942).


PHOTOGRAPH 2. A juvenile 'pseudo oleaster' olive plant (olevaster) growing naturally in a heavy grazing area.
Above: a general view.
Below: close-up.

Although all domesticated olive cultivars are considered to belong to *O. europaea*, it is assumed that some natural crosses with related *Olea* species might have occurred (Mazzolani and Altamura Betti 1972, 1979). Crosses could have occurred with species *O. laperrinii* (Batt et. Trab), endemic in sub-Saharan Africa, *O. chrysophylla* (Lam). (Syn. *O. Africana* (Mill.) found



PHOTOGRAPH 3. An olive tree kept juvenile (J) by constant pruning (simulation of grazing) and a mature (M) tree which developed from the same plant material.

mainly south of the Sahara desert and in Madagascar, and *O. ferrugina* (Royle) which is native to Afghanistan and the western Himalayas (Zohary 1970).

However, these regions do not belong to one geobotanical community and each of these *Olea* species is adapted to different environmental conditions. Thus the probability of involvement in the genome of the common domestic *O. europaea* cultivars is rather small (Zohary and Hopf 1993). The possible connecting link might be via the *O. laperrini* which might have had some meeting-points with the *O. europaea*. It should be kept in mind that wild endemic olives have been found in many geographic regions with a warm subtropical climate, including Australia and New Zealand. These wild olives were all classified as different *Olea* species but could also be considered ecotypes. It was shown, however, that some of these species can develop fruitful progenies (Ciferri 1950b, Zui-Jun et al., 1984). The purpose of current genetic studies is to establish conclusive evidence in this respect (Lavee 1990). The systematic grouping of the different olive populations and ecotypes into different genetic *Olea* species was widely described by Ciferri (1942, 1950a) and summarised for comparison with other mostly older classifications by Morettini (1972).

It is quite clear, however, that the Oleaster types in the Mediterranean basin give a fertile F1 population when crossed with the domestic cultivars as all originated from *O. europaea*.

Special attention has been directed in recent years to a sweet olive growing natively in the south of Saudi Arabia (Collenette 1988). It is not clear yet if these olives should be considered as a subspecies of *O. chrysophylla* or of *O. europaea*. No crossings of this sweet clone with common olive cultivars have been reported. On the other hand, crosses between *O. europaea* and the Asian *O. cuspidata* Wall. are currently being studied.

Recently, some workers (Green and Wichens 1989) introduced the approach of widening the botanical groups also for olives. These workers considered most of the different *Olea* groups as one diverse species – *Olea europaea*. A more 'liberal' classification uses the more modern term, «sub-species» for the different ecotypes and thus considers them as *Olea europaea* var. (Browicz and Zielinski 1990). The chromosome number of all the *olea* species is 2n=46 and attempted crosses have been successful. It seems therefore that the eco-subspecies approach is the most logical for describing and classifying the olive types found in the different regions of the world.

BIOLOGICAL AND MORPHOLOGICAL CHARACTERISTICS

THE TREE: A GENERAL DESCRIPTION

PHOTOGRAPH 4. Dwarf Trees of cv. *Amigdalolea nana* (AN) in comparison to trees of standard sized cultivars.

PHOTOGRAPH 5. A young olive tree with juvenile leaves on its lower part and mature leaves on top.

The mature domestic olive is genetically medium-sized although in extreme cases can reach a height of 10 m. The natural crown is round, though erect types are known. Until recently no true dwarf types were known. However, various cultivars developing relatively small trees are known and some of them are used and grown commercially, i.e. Amygdalolea nana (photograph 4). A semi-dwarf type of cv. Manzanillo is also known but in this case the dwarfism was suggested to be the result of a virus infection (Lavee and Tanne 1984). Recently some genetic dwarf material has been received due to some crossings both by Fontanazza (personal communication) and in our work. However, not many of the types found so far reached maturity.

The olive is a polymorphic tree which has a juvenile phase with distinctly different leaves from those of the adult phase (photograph 5). This polymorphism is notable only on trees developed from seeds or when mature trees are drastically cut back to the base of the trunk. Vegetatively propagated trees do not develop the juvenile leaf form.

As a Mediterranean tree originating from a dry, subtropical climate, the tree adapts very well to extreme environmental conditions such as drought and high temperature. Although the olive requires aerated soils, it can adapt itself to a wide range of different soil types and is resistant to low temperatures of a few degrees below 0ºC. The size of the tree and its fruiting potential are closely related to the environmental conditions. In cool climates, trees are usually smaller than under warmer growing conditions, as long as there is no serious lack of water. Most olive cultivars respond well to luxury conditions of irrigation and nutrition and are appropriate for semi-intensive cultivation with vigorous growth and high fruit yield. The olive is an alternate bearer under all growing conditions and needs horticultural intervention to minimize or prevent this. Fruiting alternation is related both to the amount of annual growth and endogenous metabolic factors. Both the vigour and amount of the annual vegetative growth and fruit size are highly dependent on the level of fruit load so that, in years with a heavy yield, the growth of young shoots is limited. The olive tree requires high light intensities for flower bud differentiation and shoot development and in most cultivars the fruit is located on the crown surface (Tombessi and Cartechini 1986).

The tree has an unusually high morphogenetic potential and thus responds well to pruning for reshaping and rejuvenation. Vegetative reproduction potential, however, varies greatly amongst the various cultivars – some take root easily, some with the greatest difficulty (Hartmann and Kester 1968, Nahlawi et al. 1975, Avidan and Lavee 1978). In spite of the high morphogenetic potential of intact olive tissues of all cultivars, the rooting of excised shoots of some cultivars is very difficult as is the regeneration of plants from excised growing points or in vitro grown callus (Rugini 1993). Only true juvenile tissue such as cotyledon fragment can be readily morphogenetically induced (Canas and Benbadis 1988). Only a few cases have reported the isolation of viable protoplast (Adiri N., MSc Thesis, Hebrew University of Jerusalem 1975, Rugini 1993, Canas et al. 1987) but most of these did not undergo a morphogenetic process leading to plantlet development.

The olive flowers in late spring (April-May) in the northern hemisphere. The tree develops a large number of inflorescences with 10-35 flowers each. Fruit set is between 1-3% and ocasionally is more than is needed for a good yield of high quality fruit. As a result, in some years it is necessary to thin the fruit. The fruit develops throughout the summer and reaches green maturation for preserving during September and October depending on the cultivar and fruit load. Colour change starts after this and full ripeness in most cultivars is reached only in winter. In most countries and particularly in dry ones, harvest for oil pressing starts after the commencement of the rainy season, regardless of the true maturation stage. This is one of the factors involved in annual quality variation in traditional orchards as the standard timing for harvest, without taking into account the level of yield, means that the fruit is harvested at different stages of ripeness.

THE ROOT SYSTEM AND ITS DEVELOPMENT

Olive seedlings develop a root system that is dominated by a central leading root. If a young plant is not transplanted, this central root will be the major root system for 4-5 years after which major lateral roots will begin to develop. Once a seedling is transplanted, it will develop a lateral root system regardless of the stage of development and age at which the seedling was transferred (Hartman and Kester 1968).

Vegetatively propagated plants form a multi-leader root system from the outset. Furthermore, plantlets with a single root do not usually grow vigorously but form an unbalanced tree which often fails to develop into a normal mature tree (photograph 6).

In vegetatively propagated olive cuttings, root initiation starts from the cambial region of the cutting and has to overcome the barrier of a highly lignified perivascular fibre layer before emerging (Beakbane 1961). The young roots of the olive are whitish in colour and contain typical root-hairs of dicotyledons. With advanced lignification of the older roots their colour turns brown (Avidan and Lavee 1978).

The distribution of the root system depends on the texture and especially the aeration of the soil. In aerated soils the angle of the root system is relatively narrow and roots can reach a depth of 6-7 m and even more. In less aerated soils the angle increases and the depth of the root system decreases. The olive root system can also adapt to heavy unaerated soils by developing a very shallow and extremely wide root network. In soil profiles that lack uniformity the olive was found to develop split root systems according to the suitability and particularly the aeration of the soil layers. In these cases, a major root leads down from one system to the next. In irrigated orchards, the olive root system is relatively shallow. Most of the roots are concentrated in the upper 70-80 cm layer and only a few scattered roots develop in the deeper layers up to 1.5 m.

Each major root is directly connected to one of the scaffolds creating sectorial interaction between each root and a specific section of the crown so that

PHOTOGRAPH 6. Root distribution on a vegetatively propagated olive cutting.

unbalanced canopies may develop depending on soil conditions. Removal of a scaffold will cause the decline of the corresponding root system and new roots will develop in connection with the growth of a new scaffold.

TRUNK AND SCAFFOLD DEVELOPMENT

The trunk of the olive tree, from the functional point of view, is a conglomerate of different independent sections. It combines the independent vascular systems connecting the different scaffolds to their roots. The trunk has an irregular diameter due to a reduced growth rate at the meeting regions of the various root shoot connecting strands. Thus the shape of the trunk changes dynamically according to the degree of development of each scaffold. This growth pattern leads to the typical fluted trunk in older trees (photograph 7). The base of the trunk usually widens while the trees mature (10-15 years), depending on growing conditions and the cultivar. This collar contains the root neck region which in the olive is very short and in many cases the beginning of the major roots can be seen above the soil surface. The collar in self-rooted trees from cuttings is considerably smaller than in trees grafted either on seedlings or vegetative rootstocks and in certain cultivars is very small and insignificant, particularly under irrigated conditions.

PHOTOGRAPH 7. The fluted trunk of an old olive tree in response to the growing scaffolds.

In grafted, non-irrigated trees the base might reach a diameter even five times wider than the major trunk. This is particularly so when the rootstock and scion are not fully compatible. The low area of the olive trunk has an extremely high morphogenetic potential and has sometimes been used in the past for woody section with bark for the mass propagation of some cultivars, i.e. Koronaiki in Greece (photograph 8). and Chemlali in Tunisia. The trunk in most cultivars produces spheroblasts which are swollen regions with a high morphogenetic potential. In the past the spheroblasts, particularly those containing a developing sucker, were cut out and used for propagation. The cuts give rise to the development of new spheroblasts. In some cases, these are of considerable size, reaching to a diameter of up to 30 cm (photograph 9).

PHOTOGRAPH 8. An olive nursery plant developed from a wood section cut out from the base of a cv. Koronaiki trunk.

The bark and wood of the olive trunk is very different in irrigated and non-irrigated trees. Under dry land conditions, the trunk develops a rather thick corky layer while on irrigated trees the bark is thin and often the tissues are viable right up to the surface and the cells contain small amounts of chlorophyll. The xylem elements of the olive are thin and develop tylosis when injured (Fahn 1975). Application of gibberellic acid causes a considerable enlargement of their diameter (Badr et al. 1970a). The dead secondary xylem – the wood – in non-irrigated trees is compact and hard with some brown phenolic deposits. The wood of irrigated trees is white and relatively soft. Lignification in fast-growing cultivars, such as cv. Barnea, is slow particularly at the root neck and young, fertigated trees tend to break at that region in strong winds. Most cultivars withstand windy conditions though some, such as cv. Leccino, are more sensitive and grow slanted in the direction of the wind (photograph 10).

The angle of shoot branching on the trunk is cultivar-dependent and the degree of elasticity of the branches varies. The branches of some cultivars tend to bend strongly under a heavy fruit load (cvs. Manzanillo, Koronaiki and Chemlali) while others might break at the crouch angle (cv. Amphisa). The inner wood of the trunks of old trees frequently rots away and the tree becomes hollow (photograph 11). This does not affect the annual growth and productivity of the tree but might encourage breakage. In such cases, new

PHOTOGRAPH 9. A typical spheroblast on a mature olive trunk.

trunks will develop from the perimeter of the base of the old one and 2-3 trees might develop in place of the original one. In many olive-growing countries, the old hollow trunks are filled with stones or concrete to minimize breakage. This internal rotting and breakage of old trees is the reason for the relatively small number of old trees (200-300 years) growing with their original trunk. It is therefore often very difficult to determine the age of such old trees as they lack the original internal wood. On the other hand, large pruning wounds due to scaffold removal in most cases do not need any wound treatment as tylosis rapidly closes the wounded tissue. Dryness only very rarely penetrates deep into the scaffold before new latent buds develop giving rise to new shoots which control the viability of the tissue around the wounded area.

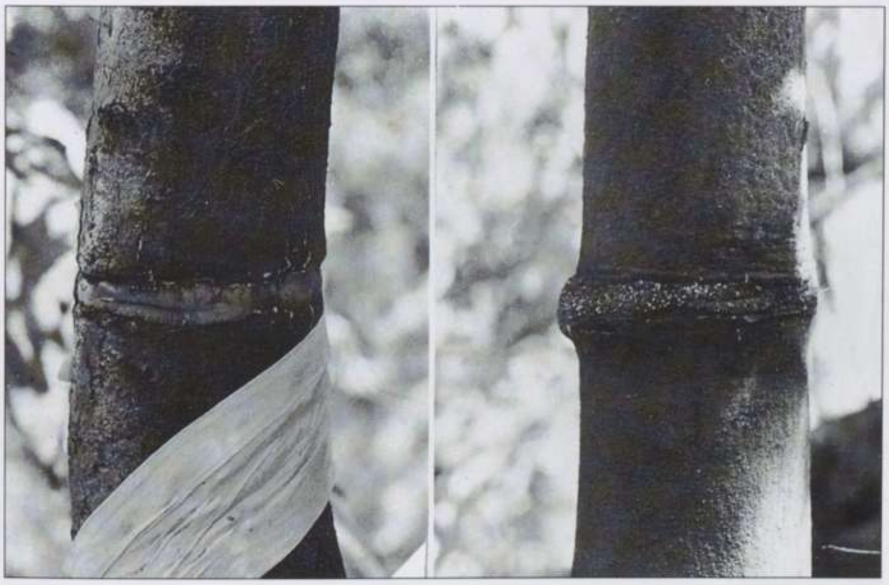
Callus formation at wounded areas is very limited under natural conditions and a special wound dressing to enhance callus formation has been developed (Lavee 1963). When girdling techniques are applied for controlling fruiting, the girdled area has to be tightly closed to maintain high humidity in the wounded area which enhances a rapid and rich callus formation (photograph 12).

Any trunk or scaffold area exposed to light for a few weeks in the spring or summer will allow the outgrowth of new shoots from latent or newly differentiated buds in the exposed area. However, overexposure to direct radiation might cause sunburn and canker development. Thus, although the olive is adapted to the dryness and high temperature and light conditions of the subtropical climate, it is essential to whitewash the trees after drastic renewal pruning (photograph 13).

In most cultivars, the young branches of the olive are green when they start to grow out of the bud. The form of the shoot just below the growing point is square. About 2-3 cm below the apex the shoot becomes round. In the very young square shoot, a lignified strand of the perivascular fibres is found in each angle stretching lower in the shoot to a concentric lignified layer. The growth rate and maturation of the shoot depend on both the cultivar and the environmental conditions. The strongest, fully-developed branches will turn into scaffolds by natural competition or horticultural selection. The main scaffolds are very similar to the trunk and have a similar potential to develop latent buds when cut or exposed to light. On the other hand, spheroblasts do

PHOTOGRAPH 10. The effect of wind on the growing habitat of cv. Leccino olive trees.

PHOTOGRAPH 11. An old hollow olive trunk with normal young annual growth.



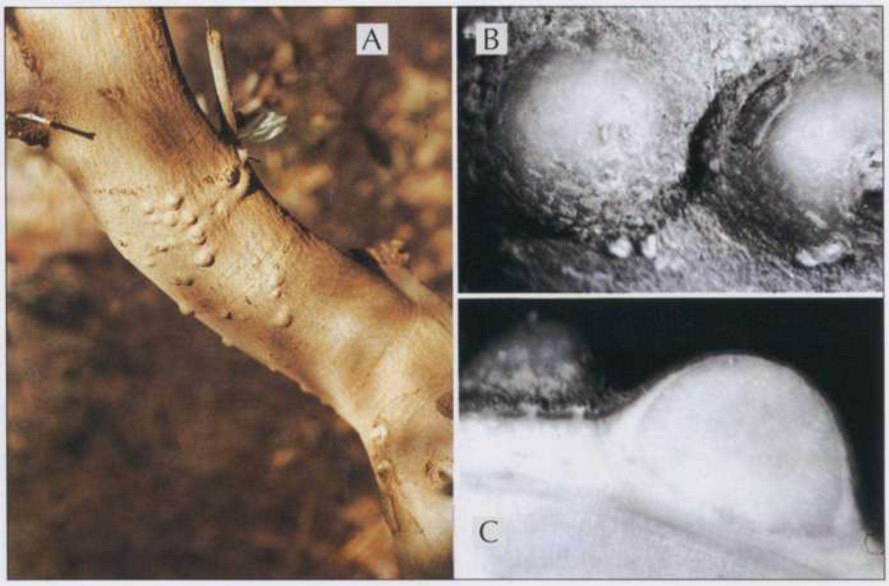
PHOTOGRAPH 12. Callus development in a girdling wound covered with a polyethylene band. Left- on mature scaffold. Right- on young vigorous scaffold.

PHOTOGRAPH 13. Whitewash for sunburn protection on severely pruned olive trees of cv. Manzanillo for canopy renewal.

not usually develop on the scaffolds unless they originate very low on the trunk. The potential for root formation on sections taken from the upper trunk and scaffold is considerably lower than from the lower part of the trunk. In some cultivars microspheroblasts can be found on 2-5 year-old shoots, scaffolds and the trunk. These microspheroblasts, when found in groups below the crouch angles of the branches, are an indication of a virus infection (photograph 14). In some cultivars, such as cv. Manzanillo, dwarfism sometimes arises, mainly due to rather soft branches which bend down even after lignification. The bark of young branches is usually thin and develops a grey-green colour which varies from one cultivar group to another. Buds form on the young shoots in pairs on alternating planes along the shoot.

LEAF ANATOMY AND FUNCTION

Olive leaves have a polymorphic leaf development. Juvenile leaves on seedlings are small, round or slightly elongated, succulent and with a high chlorophyll content, thus having a dark green colour. In most cases they are



PHOTOGRAPH 14. Microspheroblast on scaffold of a Spherosis virus-infected dwarf cv. Manzanillo tree. (A-group, B-surface, C-section).

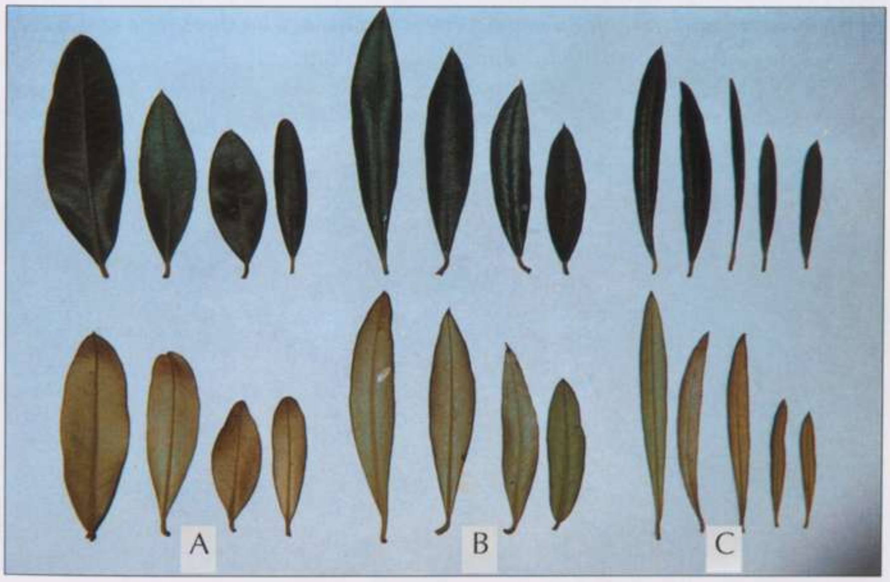
very dense, developing a compact green area (photograph 15). Their life span is similar to that of leaves on mature trees or even longer and depends on the length of the juvenile phase and the general rate of development of the plant. The leaves on vigorous suckers emerging from the base of the tree are very similar to juvenile ones in their form, but are less succulent and in many cases are able to expand to a larger size. The transition from the juvenile leaf form to the adult one is gradual and many intermediate forms are found at the transition stage.

The adult leaf of the olive is usually elongated and spindle-shaped. Some narrow elongated forms are called Lancifolia. Wide forms are also known and typical for some cultivars, notably the cv. Kalamata. Some cultivars in Greece and the eastern Mediterranean have more rounded, greyish leaves (photograph 16), such as cvs. Shami and Hallili. In our breeding work we found in many cases a relation between leaf and fruit shape although no real genetic link could be shown on a statistical basis.

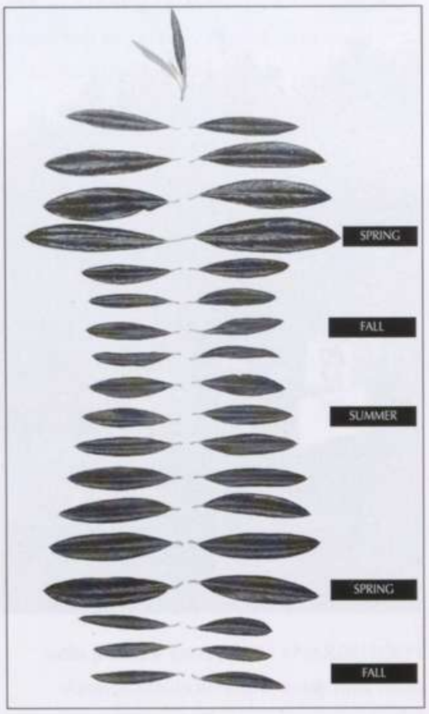
The average olive leaf is about 5-6 cm long and 1-1.5 cm wide at its middle. Leaf shape, size and characteristics may differ significantly from one cultivar to another but the major characteristics are similar for most varieties. All olive leaves have smooth margins and only a short pedicle. The size of the leaves of most cultivars varies considerably according to plant age and vigour and environmental conditions. Furthermore, a sequential change in leaf size is apparent on the annual shoot during the growing season (photograph 17). The first pair of leaves developing from the bud in the spring is usually smaller than average. Most of the subsequent leaf pairs growing during early spring are longer than average with a larger surface area. With the reduction of vegetative vigour in the summer, new leaves tend to be progressively smaller. In autumn, particularly in climates where a marked second growth flush occurs, the size of the new leaves increases again.

The leaves have a central vein which, in most cultivars, protrudes on the lower, dorsal side. On the upper surface, the ventral side, there is no rule as to whether the central vein protrudes or is sunk in the surface. In most cultivars the leaves are somewhat concave along the narrow axis in the lower, dorsal direction. There is also often a slight bending and twist along the major axis of the leaves.

PHOTOGRAPH 15. A young seedling olive plant with dense small succulent juvenile leaves.



PHOTOGRAPH 16. Typical leaf forms of different olive cultivars. A-broad, B-spindle, C-narrow.



PHOTOGRAPH 17. Seasonal leaf development during shoot growth of cv. Manzanillo in an irrigated orchard in California.

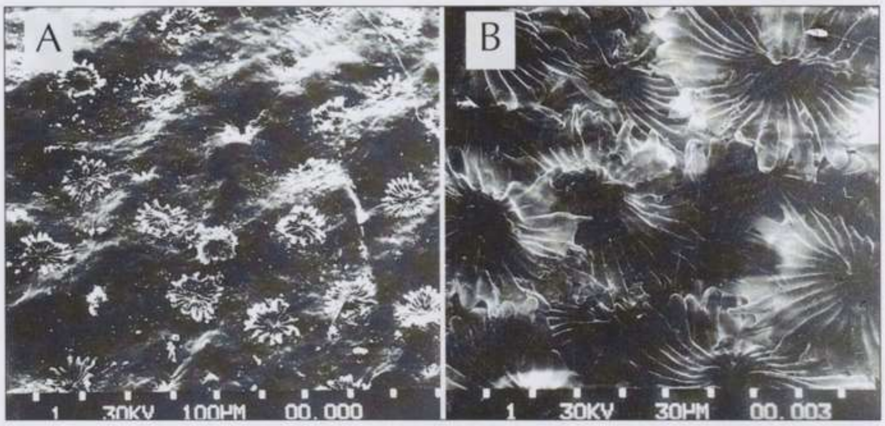
The secondary veins usually leave the central vein at an angle of 45° and are slightly apparent on the upper surface. The lateral veins are usually connected near the edge of the leaf to a circular vein system surrounding the whole leaf near its edges.

The upper surface is dark green and shiny. This is due to a waxy cuticle which is secreted from the epidermal cells and covers the upper surface of the leaf. The cells of the upper epidermal layer are uniform and have a rather thick cell wall.

In addition to the waxy layer, some epidermal cells on the upper surface of the leaves develop a multi-cellular leaf plate which has a stem usually of 2 cells and an umbrella-like cover with up to 32 radial cells (photograph 18A). The edges of these cells are often turned slightly downwards. The cells of the plate are transparent and do not contain chlorophyll but have a relatively large number of organelles in the cytoplasm. These leaf plates on the upper leaf surface are distributed loosely over the whole upper surface and do not overlap. Broken leaf plates from the upper leaf surface, after decompartimentation, have a high peroxidase activity. It has been suggested that they have a function in protecting the olive leaves from pests and diseases (Siegal and Lavee, unpublished). The initial leaf plates are already formed in the primordial phase of the leaves (photograph 19) although new plates can be formed on mature leaves, particularly to replace injured and broken ones.

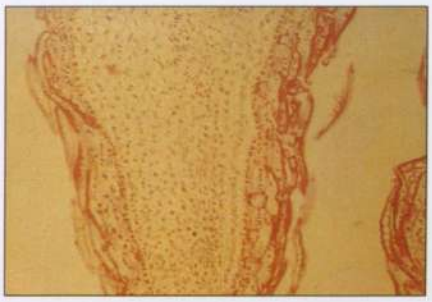
The epidermis of the upper surface of olive leaves does not develop stomata. Below the upper epidermis are 2-3 layers of palisad cells. These cells contain a large number of chloroplasts with a high chlorophyll content. Below these is the network of small veins and scleroids that give the olive leaf its rigid form (Fahn 1975). Beneath the veins and scleroids is the spongy tissue which contains large amorphic cells. The lower epidermis contains both the stomata and an extrmely large number of overlapping leaf plates (photograph 18B). These plates create a layer 3-4 deep covering the stomata and create around them a distinct environment (Morettini 1972). They thus function as one of the mechanisms of the olive tree to overcome extreme drought conditions by creating an independent favourable atmosphere around the stomata, regardless of surrounding conditions. The leaf plates on the lower side of the leaves are larger than those on the upper surface, do not contain many organelles and have only a very weak peroxidative activity when broken off. The multiple layers of leaf plates on the lower surface of olive leaves are responsible for their silvery colour.

The amount of leaf plates on the lower surface is genetically determined and is thus typical for each cultivar (Ruby 1917). The stomata of olive leaves



PHOTOGRAPH 18A. Leaf plate on the upper (ventral) surface of an olive leaf.
PHOTOGRAPH 18B. Densely distributed leaf plates on the lower (dorsal) side of the leaves.

develop relatively late in leaf ontogenesis and become apparent only when the leaf reaches about 20-25% of its final size.
The life span of an olive leaf is up to 3 years but most drop in their second year during the new growth and when the leaves are becoming shaded. They drop by the activation of an abscission layer present at the proximal end of the petiole. Owing to their self-created, independent environment, detached leaves remain active for many hours keeping a constant respiration rate (Lavee and Martin 1981). The collapse of detached leaves occurs after about 20 h as measured by changes of CO_2 and ethylene evolution. The photosynthetic potential of the leaves and their function in controlling bud differentiation is dealt with elsewhere. The olive leaf shows nutritional deficiency and stress symptoms only under severe conditions. The most common expression of such conditions is loss of the dark green colour of the leaves. Under severe water stress, partial yellowing and unusual leaf drop might be noted on only one part of the tree owing to the sectorial root system.Olive leaves are very sensitive to limitation of light and will shed under such conditions. The photosynthetic gradient between illuminated and shaded leaves is very great (Bongi et al. 1989) and the inner leaves of an olive tree are very inefficient in photosynthesis. Furthermore, extreme environmental conditions such as high or low temperature cause developmental stress accompanied by a marked reduction in the activity of the photosynthesis apparatus (Bongi and Lang 1987). On the other hand, it has been found that *in vitro* grown olive callus requires only an extremely low light quantity, intensity and duration in order to induce rapid and intense chlorophyll biosynthesis (Lavee and Messer 1969).



PHOTOGRAPH 19. Leaf plate development on initial leaf primordia still part of the bud central cone.

BIOLOGY OF BUD DIFFERENTIATION, FLOWERING AND FRUIT SET

CONDITIONS AND TIMING FOR REPRODUCTIVE BUD DEVELOPMENT

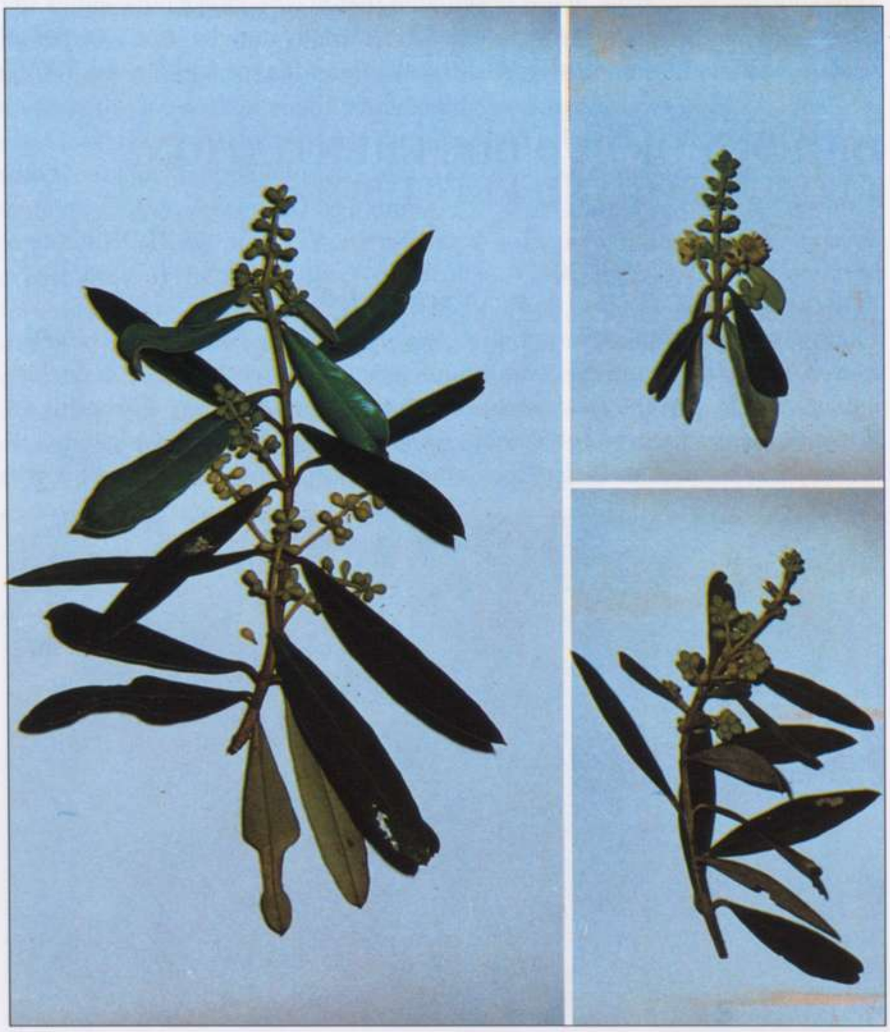
Flower bud initiation, differentiation and development are usually referred to as a relatively short and continuous process dependent on the performance history and the environmental conditions of the tree. Flowering in the olive occurs nearly exclusively on shoots which developed vegetatively in the previous season. Buds which remained dormant during the spring fol-

PHOTOGRAPH 20. Olive inflorescences on 2- (left) and 3- (right) year-old branches in Perugia, Italy

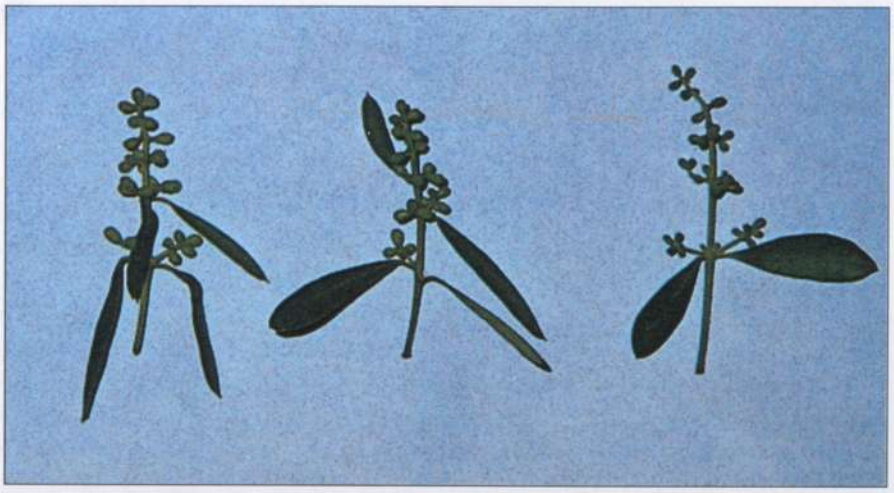
lowing their development do not produce inflorescence under normal growing conditions. These buds can and do frequently sprout but produce only vegetative shoots. Only extremely few cases are known (Fontanazza personal communication) in which inflorescences developed from buds on two or three year-old branches (photograph 20).

In the past it was accepted that only the buds which developed during the spring and summer growth could differentiate and flower in the following spring. The buds on the distal portion of the shoots which developed in the autumn are usually flowerless. This, however, seems to be the case only in cooler regions where the autumn growth is late and short and often does not fully lignify before the spring. In warmer climates, particularly in years following a relatively cold winter, inflorescences were found to develop also from buds on the autumn growth and even from the most distal bud or apex of the shoot (photograph 21). But flowering on the apex, even if no fall growth occurred, is rare and will take place only under specific, inductive environmental conditions. This is particularly the case in some years with the Sfax Chemlali cultivar (Trigui, personal communication).

In contrast to most other woody fruit species, olive buds do not have bud scales and all the leaflets of the buds, including the most external ones, are leaf primordia which will develop into normal leaves unless inflorescence differentiation occurs. When normal inflorescence induction and differenti-



PHOTOGRAPH 21. Inflorescence development from apical buds of the autumn growth after a cold winter in warm climates.



PHOTOGRAPH 22. Inflorescence with various leaf developments on the rachis.

ation take place, the leaf primordia stop their normal development and turn into bracts at the main branching points along the inflorescence. These abscise during the development of the inflorescence. The early supression of the development of leaf primordia in differentiated buds is occasionally not complete and various degrees of leaf development can be found at various locations within or at the base of an inflorescence (photograph 22).

The initial development of olive buds in the axil of growing leaves reaches in most cases 4-6 pairs of leaf primordia once the developing leaf near the bud reaches its final size. The leaf primordia are formed by lateral development of three layers of mother cells in the distal end of the bud's central cone (figure 2). After that, the bud is in a dormant state with very little further visible development until the early following spring. The leaf primordia in the bud are arranged in pairs. Each pair is located on a separate plane. The leaf primordia of each plane are opposite to each other. The different primordia pairs are arranged at a 90º angle from each other, so that every second pair develops exactly on top of the other. The cone in the centre of the bud re-

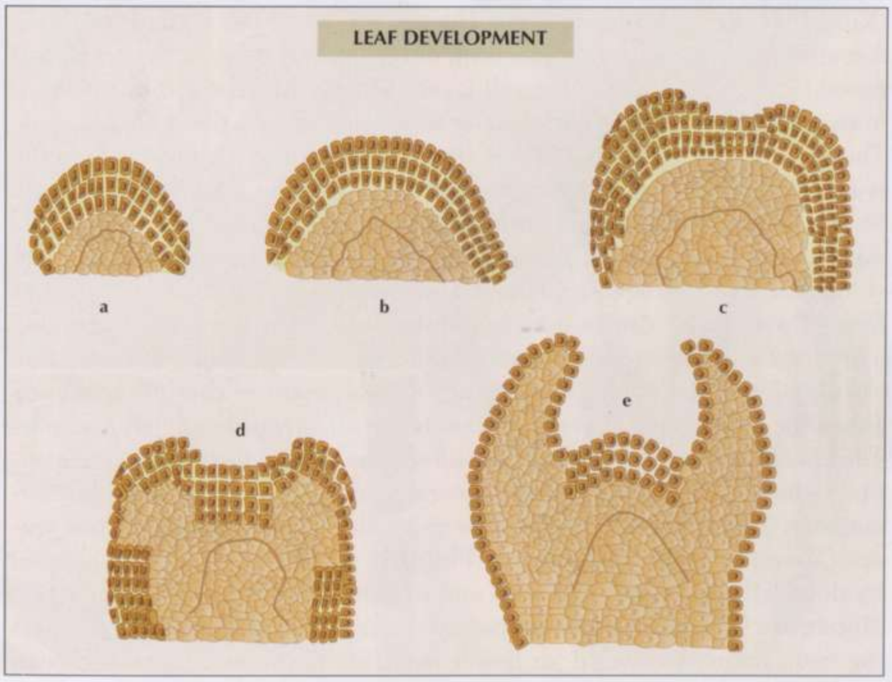
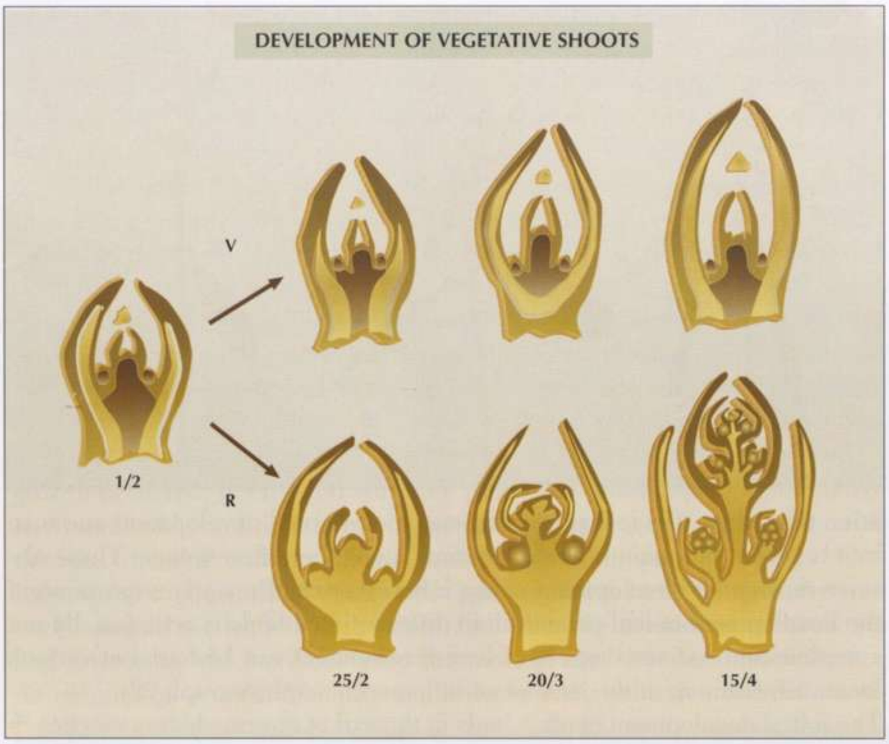


FIGURE 2. The development of leaf primordia (Stages a-e) on the central cone of olive buds. (According to Troncoso 1966).

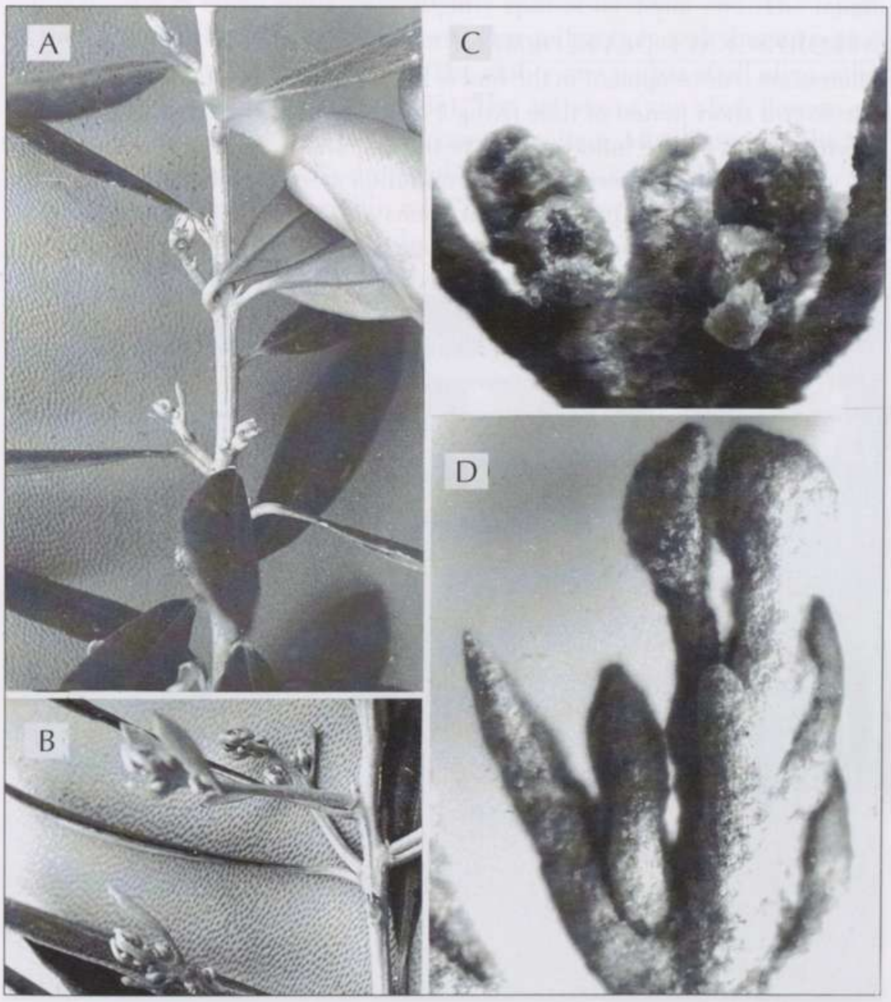
FIGURE 3. The development of vegetative (V) and reproductive (R) olive buds during winter and spring (Feb. 1-Apr. 15), showing the arrangement of leaf and floral primordia.



mains undisturbed until the start of further vegetative or reproductive development in the following spring. This alternating arrangement of the leaf primordia is typical for all the *Olea europaea*. The 90º angle between the leaves also applies to the arrangement of the flowers on the inflorescence.

Morphological differences between vegetative and reproductive buds are already noticeable endogenously by the autumn (Pinney and Polito 1990) but visually only in late winter or early spring with the beginning of active bud development prior to the annual main growth period. Changes in the buds during the differentiation process have been described by many workers (King 1938, Troncoso 1966, 1967, Hachett and Hartman 1963, 1964). Differentiation starts with the widening of the central cone in the buds, followed by rearrangement of the cell layers underneath. The initial embryonic tissue of the growing point usually differentiates into the 3 king flowers. The secondary buds in the axil of the various primordia develop into the lower flower initials on the lower side branches of the inflorescence (figure 3). At this stage the leaf primordia lose their potential for further development and turn into bracts. Within each flower, the petals are the first to develop and shortly thereafter (about 1 week) the sepals differentiate. After about 2 weeks, the stamen initiate and the pistil is the last organ to develop a few days later. The whole process of differentiation per inflorescence takes about 4-5 weeks. Thereafter, further development of the inflorescence should be considered a growth process of the already existing floral organs.

The conditions leading to olive bud differentiation and its timing are not entirely clear. Until recently, it was generally accepted that flower bud differentiation occurs in mid-winter on the vegetative growth of the previous season (Morettini 1938, Wigodsky de Philippis A. 1937). This was supported by defoliation experiments with and without girdling (Hartmann 1951, Morettini 1951) pointing to the period of mid-January to mid-February as the main induction period for flower bud differentiation. It has also been suggested (Hackett and Hartmann, 1963, 1964, 1967; Hartmann 1953; Hartmann and Porlingis 1957) that chilling is required for the induction and development of the differentiation process. Induction refers to the chemical change in the cells starting the process leading to floral development. The anatomical changes characterizing floral development are referred to as evocation or initiation, while the beginning of visible specific floral organ formation is referred to as differentiation. Both the time of floral induction and the direct requirement of chilling have been questioned by Lavee as early defoliation in September occasionally does not prevent differentiation. Furthermore, in some warm regions with only a negligible amount of chilling hours, record olive yields have been recorded. This was recently supported by the work of Fernandez-Escobar et al. (1992) and by Rallo and Martin (1991) who claim that induction occurs in July. Furthermore, Pinney and Polito (1990) showed that cytochemical changes in buds are already occurring in the autumn, leading in some cases to differentiation in October and November. It has recently been suggested (Rallo and Martin 1991) that the chilling requirement reported for olive tree flowering is independent of the process of flower induction and differentiation and that chilling is required to overcome flower bud dormancy. By analysing the long-term climatic conditions in Israel in relation to fruiting, we concluded that induction for flower bud differentiation is already occurring in mid-summer (Lavee, in preparation). It seems that even in cool growing regions flower bud induction is dependent



PHOTOGRAPH 23. Incomplete differentiated olive flower buds on semi-juvenile plants under highly inductive conditions.
A. Shoot with initial abnormal inflorescence.
B. Elongated 'juvenile' inflorescences.
C. Abnormal flower bud.
D. Elongating inflorescence with undeveloped floral tissue.

on the fruiting and growth history of the tree. However, this initial induction will arise only if winter conditions are suitable. We have shown (Lavee and Harshemesh 1986) that, under highly inductive conditions of controlled summer growth and winter chilling, differentiation can start even on semi-juvenile seedling plants (photograph 23). This differentiation will only rarely develop into normal flowers because of the partially juvenile state of the plants. In earlier work, Hartmann and Whisler (1975) showed that buds on young olive plants could be induced to differentiate throughout most of the year when suitable environmental conditions were artificially created. Thus a two-step theory for olive flower bud differentiation is being suggested, according to which we assume that buds receive their initial induction for differentiation in the summer while a second stimulus is required in the winter. The process will only occur if inductive conditions prevail in both seasons. Under natural conditions, the fruit is borne on shoots which developed in the previous season so that buds receive the initial impetus for potential reproductive differentiation during the active growth of the tree. This growth and susceptibility to the induction impulse depend on endogenous factors governed by the developmental conditions of the tree and its present and past fruiting history. On the other hand, differentiation leading to the development of flower buds is mainly dependent on the environmental conditions such as chilling or day/night temperature fluctuations during the winter. These relations will be further discussed below.

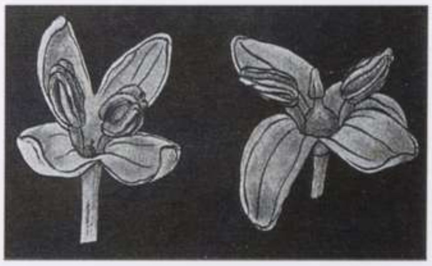
INFLORESCENCE DEVELOPMENT

Inflorescence development in the bud is fairly uniform. Most flowers differentiate over a short period of time (King 1938). The time span from first flower differentiation on the inflorescence to the last one is usually not more than 1-2 weeks. Once inflorescence differentiation starts, the bud continues its development uninterruptedly until it opens and the inflorescence emerges. The initial growth of the inflorescences is uniform and all their parts grow simultaneously. Once the inflorescence has fully emerged and reached a length of about 2 cm, the rachis starts to elongate rapidly and, when the inflorescence reaches about 2/3 of its final length, the individual flowers begin to expand. The final size of the inflorescence and flowers is reached just before anthesis from mid-April to mid-May, depending on environmental conditions

PHOTOGRAPH 24. The sequence of flowering of cv. Barnea inflorescences.

and the cultivar. The colour of the growing inflorescence is green and the chlorophyll is lost from the petals only shortly before flower opening when, in most cultivars, they turn white (photograph 24). In rare cases the petals on their dorsal side remain greenish until their actual opening.

The total number of flowers on the inflorescences, their distribution on the rachis and inflorescence length are genetically determined and thus specific for each cultivar. However, variation of these characters within the tree is high. The inflorescences at the proximal and distal ends of the shoot are usually smaller and at the proximal end also develop fewer flowers. The size of the inflorescences and number of flowers vary also from year to year in accordance with the physiological state of the tree and climatic conditions. The specific conditions leading to smaller or larger inflorescences are not yet entirely clear.



PHOTOGRAPH 26. Perfect open flower (Right) and male flower (Left).

FLOWER MORPHOLOGY

The morphology of the olive flower is uniform throughout the *O. europaea* and consists of 4 fused green sepals which create a cup at the base of the flower. It has 4 white petals which are fused at their base and drop as one unit at the end of flowering. The flower has 2 stamens with a large, yellow, two-lobed anther on each. The ovary is located in the centre of the sepal cup having 2 carpels with 2 ovules each. The style is straight, short and thick with a rather large stigma. The form of the stigma varies between different cultivars and in many cultivars is slightly split at its distal end. The length of the style is also cultivar-dependent. The pollen is barrel-shaped with 3 longitudal enclaves along the grain. The anther and pollen of all olive cultivars are bright yellow (photograph 25). The anthers of the olive flowers are usually large and contain a large amount of pollen. After flowering the anthers turn brown and usually drop with the petals.

Two types of flower are found in most olive cultivars: normal endogenous perfect flowers and imperfect male flowers. Female flowers have not been

PHOTOGRAPH 25. Stages of flower development from opening to petal drop (A-F).

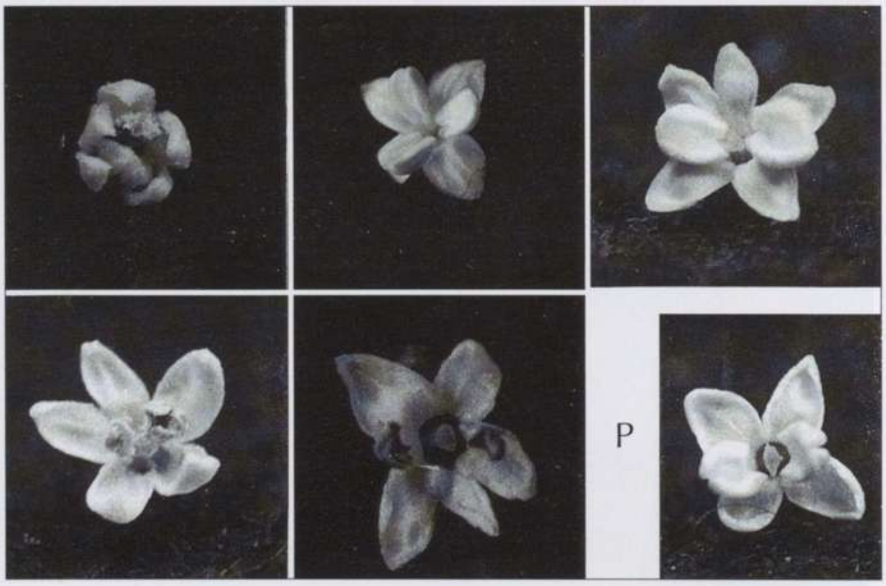
recorded (photograph 26). The male flowers develop due to a decline of the ovary in the primordial stage. Male flowers with different degrees of ovary development are usually found. In extreme cases the ovary is practically unnoticeable whereas other flowers are found with a large ovary and only a partially-formed style or stigma. The pollen of the male flowers is as viable as that developed in the anthers of complete flowers. Basically, the percentage of perfect and male flowers is genetically determined and thus is specific for each cultivar (Brooks 1948). The actual amount of male flowers, however, is strongly influenced by the development potential due to the fruiting history of each tree and by climatic conditions. Under favourable inductive environmental conditions occuring after a heavy yield, the percentage of perfect flower differentiation within each cultivar decreases considerably (Villemur et al. 1976).

In years with good flowering, fruit set of 1-2% of the flowers is enough to produce a good yield. One perfect flower per inflorescence is sufficient for maximum cropping. Thus the amount of male flowers is usually not correlated with the amount of yield (Table 1). In rare cases and with some cultivars, such as cv. Ascolano, the total male flower population might be so high in some years that fruit set is not commercial.

TABLE 1

THE RELATIONSHIP BETWEEN THE PERCENTAGE OF PERFECT FLOWERS PER INFLORESCENCE AND FRUIT SET IN THREE OLIVE CULTIVARS (Inflorescences for each cultivar were arbitrarily grouped, according to their percentage of perfect flowers, into three groups: a, b and c)

	cv Sevillano		cv Souri		cv Manzanillo	
Inflorescence group	**Perfect flower (%)**	**Fruits per 100 inflorescences**	**Perfect flower (%)**	**Fruits per 100 inflorescences**	**Perfect flower (%)**	**Fruits per 100 inflorescences**
a	5	12	25	27	35	72
b	20	14	45	26	55	69
c	35	13	65	28	75	71
MSE		4		6		6



PHOTOGRAPH 27. Various abnormal olive flowers with increased number of anthers on petals. (P. Perfect flower).

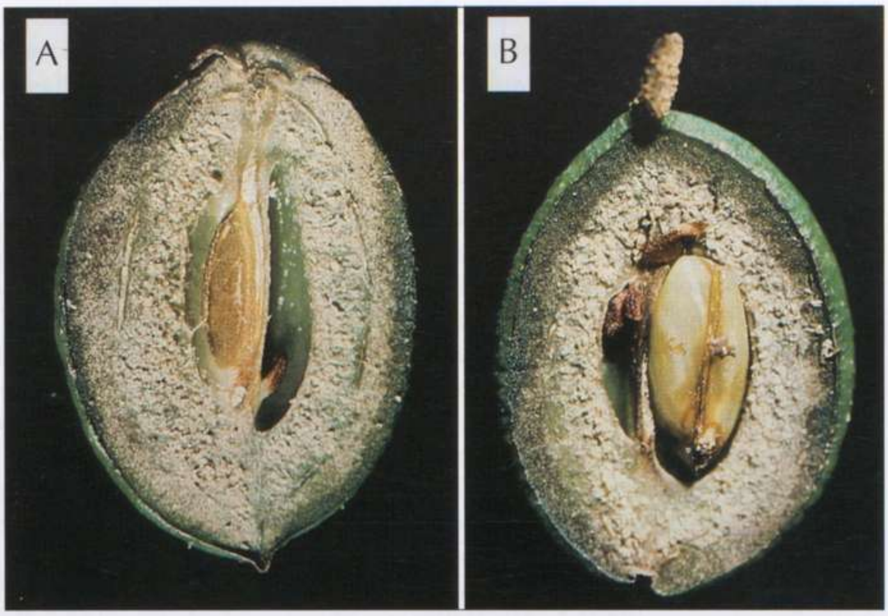
Abnormal flowers with an increased, irregular number of flower parts are occasionally found (Lavee 1985). The most common abnormality is to find 3 stamens and/or 5 petals (photograph 27). Flowers with up to 6 stamens and 8 petals have been found. Some cultivars tend to develop more abnormal flowers than others. Both the pollen and ovules of these flowers are usually fruitful. Pollination of olive flowers is mostly carried out by wind (Morettini and Pulselli 1953). Monitoring of pollen distribution (Lavee and Datt 1978) showed that pollen can be carried by wind over very long distances. An effective amount of pollen has been found at a distance of more than 7 km. from a commercial olive orchard. However, for effective pollination in the orchard, at least 10% of pollinizer trees are required to ensure a good commercial response. Various insects also enhance pollination though not very efficiently. In years with low flowering of other species, honey bees are active in olive orchards.

Climatic conditions during flowering are critical for pollination and fruit set. It has been shown (Griggs et al. 1975, Fernandez-Escobar et al. 1983) that pollen tube growth in the ovary is inhibited when the temperature during flowering rises above 30ºC. Under such conditions, very low fruit set might occur or a considerable number of inflorescences with small parthenocarpic fruits may develop (Bradely 1961). This parthenocarpic fruit will usually drop if one normal fruit sets on the inflorescence. Therefore, under high temperature conditions, cross-pollination is particularly important in order to ensure a commercial yield as foreign pollen allows normal pollen tube development in the style also at this relatively high temperature.

Some cultivars, which have a high tendency to produce parthenocarpic fruit, sometimes retain these parthenocarpic fruits even on the same inflorescence next to a normal fruit. Cultivars such as Cucco and Sevillano develop some small parthenocarpic fruits in most locations and years while others, such as Manzanillo, Ascolano and Uovo di piccione, will do so only under certain special conditions.

PHYSIOLOGY OF POLLINATION

The ability of olive cultivars to set fruit by self-pollination is genetically determined (Bradley and Griggs 1963) although the genetic expression is highly dependent on climatic and growing conditions. Many cultivars which were considered auto-sterile in one country or region were found to be self-fertile in others and vice versa (Morettini and Benetti 1942, Morettini and Vallegi 1940, Gerarduzzi 1958) although most workers found that cross-pollination increased fruit set and the yield of most cultivars (Tombesi 1971, Vidal 1969). In Israel, cv. Koronaiki is the only cultivar that sets fruit to a similar extent by both self- and cross-pollination. In some cultivars, such as cv. Lucques, self-sterility is high but even for this cultivar there is not enough evidence to determine either full genetic self-sterility or high thermal sensitivity. In some cases, ovule development might be defective even under good cross-pollination conditions and then, although pollination and fertilization occur, the embryo declines due to an abnormal embryo sac, as shown by Rallo et al. (1981) for cv. Swanhill. Although specific pollinizer cultivars have been described for various cultivars, it seems that some cultivars are the most efficient pollinizers for a wide range of different cultivars. A potent pollinizer with a wide range of responsive cultivars is cv. Uovo di piccione which, both in Israel and the US (Lavee and Datt 1978, Griggs et al. 1975), has been shown to be most efficient for cvs. Manzanillo, Mission, Ascolano and many others (photograph 28).



PHOTOGRAPH 28. Normal embryo and fruit development of cv. Muhasan (A) and Manzanillo (B) pollinated by cv. Uovo de piccione.

About 10% of pollinizer trees are usually needed in the orchard for good pollination (figure 4). This proportion may vary depending on the topography of the region, the amount of wind and the temperature during flowering. Olive pollen is readily distributed by wind and its prevailing direction during flowering has to be considered in orchard design to determine the number of pollinizer trees needed and their distribution in the orchard.

Weather conditions during flowering are critical for the potential yield. Rain during flowering minimizes pollen distribution by wind and also shortens pollen viability.

The dry desert winds occurring occasionally during olive flowering in many Mediterranean growing areas may also cause a reduction in yield although this is mostly due to their effect on the stigma (drying), style (inhibition of pollen tube growth) and ovary (zygote decline). Dry, hot winds might also cause the decline of pollinated ovaries even when no water stress develops in the tree. Under severe hot and dry conditions, the young ovaries whether fertilized or not, may harden and remain on the tree as small, hard black

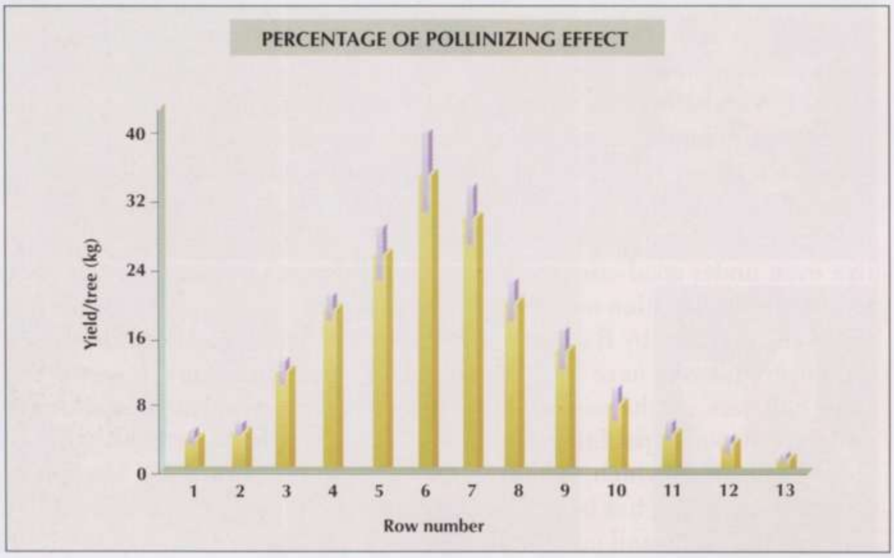


FIGURE 4. The effect of a cv. Uovo de piccione *pollinizer* row (shaded bar) on yield distribution in an isolated cv. Manzanillo orchard in southern Israel.

mummies for 2-3 months before dropping. Both hot and dry or cool and wet climates during flowering may lead to a marked increase in the number of parthenocarpic fruits.

ENVIRONMENT AND METABOLISM

ANNUAL DEVELOPMENTAL CYCLE

As for all trees, the annual development of the olive tree has to be considered as part of the long-term life span of the plant. As environmental conditions on a macro basis repeat themselves annually, tree development during each year should be considered as one developmental cycle. The cyclic approach to annual tree growth and fruiting is based on the annual repetition of the environmental conditions and a parallel yearly repetition of the developmental stages of the tree. The timing of the various annual biological stages in each tree species is the result of a long-term natural selection and adaptation of the species to its environment. The olive tree developed in the Mediterranean climate and the sequence of its developmental stages are expressed accordingly.

In the northern hemisphere, vegetative growth starts in the spring. Both apical buds and a limited number of lateral buds, which developed in the previous season, will start to grow. Temperatures above 12°C are needed to reinduce growth in the spring. The initial elongation growth is rapid, particularly in the warmer growing regions. At temperatures above 30°C in mid-summer, the vegetative growth rate drops. When there is enough moisture in the soil or under irrigated conditions, a second period of rapid growth will occur in the autumn with the reduction in daily temperatures. Thus, different types of growth curves of olive trees have been recorded in accordance with the thermal conditions in the summer. Irrigation has a major effect on the degree of thermal inhibition of vegetative growth. In most regions the olive tree has a double peak growth curve. The degree of growth rate reduction in mid-summer is a function of the height and length of the supraoptimal thermal period and growing conditions (figure 5). The

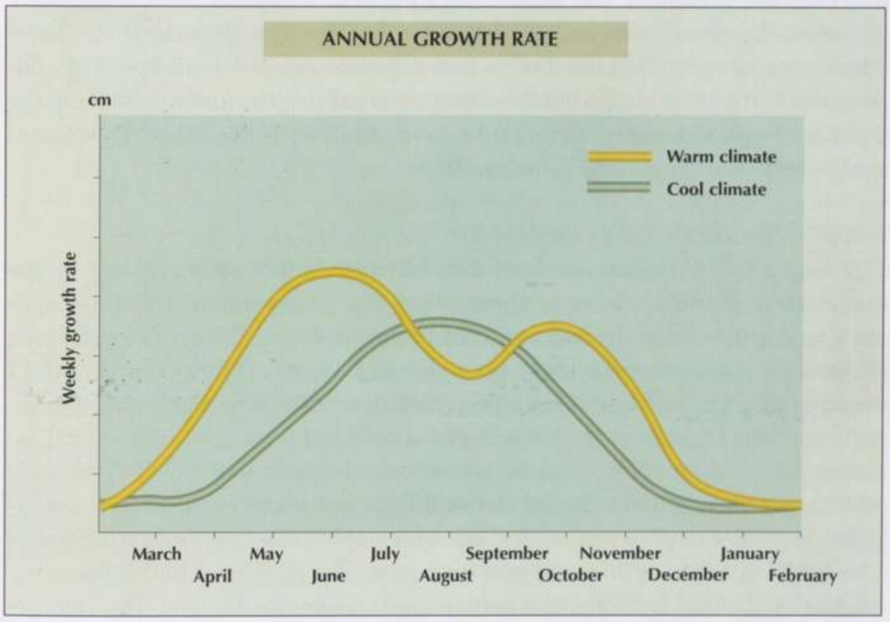


FIGURE 5. The annual growth curve of olive shoots in warmer and cooler climates.

amount of autumn growth is also dependent on the length of the optimal thermal period for temperature drop in the late autumn. The degree of growth is highly dependent also on the availability of water in the soil. This factor is super-imposed on the thermal conditions. It should be noted that in more northern regions or at high altitudes with cooler summer temperatures only a single growth peak in mid summer will occur. It should be noted that in some years and regions there might be limited vegetative growth all year round. This is due to the moderate climatic conditions which are typical of the Mediterranean basin. In some cases, particularly after a spell of hot weather in mid-winter, slight vegetative terminal growth with a red tint due to a high anthocyanin content may occur. Such red growth might appear also in the late autumn in response to a rapid temperature drop before the terminal elongation growth lignifies. In most cases, this growth will lose its reddish colour in the spring and continue to develop normally. In rare cases with continuous low temperature this growth will decline.

Leaf size is, as shown earlier, positively correlated to the growth rate. The length of the developing internodes shows a similar pattern during the growing season. The number of buds which take part in annual vegetative development is limited and is usually not more than 5-10% of the buds which developed during the previous season. In a highly reproductive «On» year, both the number and rate of vegetatively developing buds is low. But even in the «Off» year only a relatively small number of the buds is induced to grow vegetatively. In extreme cases all the buds might sprout vegetatively, but this phonemenon is due to special winter conditions related to de-differentiation of induced flower buds and will be discussed later.

During the active growing season, buds on two and three year-old shoots might also sprout but this will occur only in highly illuminated parts of the tree or due to growth stimulation induced by pruning.

The general pattern of the vegetative growth cycle is similar under all growing conditions. It will differ, however, on a quantitative basis according to growing conditions such as soil moisture, temperature, cultivation techniques, etc. Vegetative bud opening in the spring induced by the rise in daytime temperatures and longer days leads to a new growth cycle. There seems to be no specific trigger for initiating the new growth. It has been shown under controlled conditions that vegetative growth could be artificially induced by creating favourable growing conditions at any time during the year as long as mature viable buds are available on the plant (Lavee, unpublished, Hartmann and Whisler 1975).

REPRODUCTIVE DEVELOPMENT

The reproductive development of the olive tree, although dependent on the vegetative growth cycles and vigour, is partly independent. Inflorescences as a rule differentiate in buds which developed during the previous growing season so the buds that might give rise to flowers are between 3 and 11 months old. Under highly inductive conditions which include early lignification of the shoots in the autumn and a cold wet winter, even terminal inflorescence can develop. Normally, however, the buds in the axil of the most distal leaves which developed in the fall do not undergo floral differentiation. The amount of differentiated buds on a shoot can vary from 0 to 95% of the buds on the growth of the previous year. The degree of bud differentiation is controlled by both endogenous and exogenous factors. The interaction between all the factors involved leads to the degree of expression of the differentiation potential in each tree on an individual basis.

The amount of floral differentiation and inflorescence development has only a minor effect on the number of developing vegetative buds but has a major quantitative effect on vigour and rate of growth. Furthermore, the morphological characteristics of the reproductive buds are expressed only shortly before they sprout in the spring. Thus it has been suggested that the developing buds of the olive are of an indifferent nature and need to undergo differentiation for either type of further development, whether vegetative or reproductive.

The effect of temperature

It used to be generally accepted that flower bud induction occurred in midwinter and that differentiation started soon after, a rapid process at the end of which the bud opens. A chilling requirement for flower induction was described by many workers (Hartmann and Porlingis 1957).

Under natural conditions, however, induction is limited to the winter season. Hartmann and Whisler (1975) demonstrated the ability of olive buds to differentiate at any season of the year when subjected to an artificial chilling period. They also showed, with potted plants, that alternating temperatures between 4 and 18ºC were more efficient than constant chilling. On the other hand, a constant temperature of 12ºC was also active in inducing flower bud induction. Chilling requirements of 50-60 hours below 7.2ºC (cvs. Azapa and Arauka) and up to more than 1200 hours (cv. Sevillano) hare been described (Hartmann and Opitz 1977).

Nevertheless, these results cannot be accepted as the only explanation of the conditions leading to differentiation. In various regions with very little chilling, record yields were achieved with cultivars such as Manzanillo, Santa Catarina, Chemlali and many others. Furthermore, defoliation and cytological studies (Pinney and Polito 1990) showed that floral induction could be partially expressed in buds already by the autumn (October).

It has also been widely confirmed that, in relatively warm regions, the level of differentiation and flower development is considerably higher after cooler winters. This led various workers (Rallo et al. 1994, Fernando Escobar et al. 1992, Rallo and Martin 1991) to assume that the chilling requirement for flowering in olive trees is not related to differentiation (vernalisation) but is required for flower bud opening (dormancy). This, however, is somewhat doubtful as vegetative buds of olives have no chilling requirements and the majority of buds in «Off» years which are not differentiated will not sprout even after a long chilling period. It should also be borne in mind that the dormancy theory could be considered if we assume that differentiated flower buds develop a true dormant period while vegetative buds do not. This can be partially supported by our findings that the amount of chilling required for return bloom is positively correlated with the amount of yield in the previous year. From field condition calculations in various regions over 5 years we could conclude that, following a year with a higher yield, more chilling is required for the same amount of return bloom as after a year with a low yield but it is hard to visualize this type of difference only on the basis of changes in the chilling requirements to overcome bud dormancy. The relation of the low temperature to the potential flower bud differentiation also has to be clarified. Experiments with whole plants grown in containers under controlled temperature conditions also raise some questions regarding the flower bud dor-

PHOTOGRAPHY 29. The effect of chilling interruption by high temperature on bud development of cv. Manzanillo shoots. Left. control. Right. interrupted chilling.

mancy hypothesis in the olive. It has been shown in Israel that breaking up the winter chilling by a 10-day period of hot temperature in mid-January resulted, under outdoor conditions, in vegetative sprouting in the spring of all the buds from the previous season's growth. The buds on shoots with an unbroken chilling period gave rise to inflorescences (photograph 29). Thus either a process of de-differentiation occurred or a block in the pathway leading to differentiation took place. It should be noted that, with the interrupted chilling, all the buds opened vegetatively and this would not occur under normal conditions. A similar phenomenon was occasionally observed in Israel under field conditions and could be correlated to a similar natural hot period in the winter.

Analysis of annual production in warm regions showed some odd years which did not follow yield expectations based on the previous year's production. In some cases when a high yield was expected, actual production was low and, in others, two successive years with high production were also recorded. In most cases, these results could be explained on the basis of the winter temperature. Cold winters induced flowering to levels that were higher than expected on the basis of the previous yield. Warm winters, on the other hand, reduced flowering to a level considerably lower than was expected.

The temperature relation cannot account for all these odd years, there being some cases where the level of flowering cannot be explained on the basis of the previous fruit yield or winter temperatures. These observations and the occasional appearance of floral buds in the autumn led us originally to the idea that floral differentiation of olive buds was initiated by a 2-stage process.

Timing of floral induction

It has been suggested that initial induction determining the floral differentiation potential of olive buds takes place during the summer (Rallo and Martin 1991). This induction would correspond to that occurring in most other fruit tree species. Summer induction depends mostly on the endogenous metabolism resulting from the performance history of the tree. The responsiveness of the bud to the metabolic state of the tree also depends on its state of development and maturation. Therefore, the rate of growth and development of the shoot during the year play a major role in its fruiting potential the following year. The developing bud probably has to reach a specific degree of maturity before it can be receptive to flower-inducing conditions. Thus, floral induction can occur throughout the growing season in accordance with the state of the buds available to receive the induction. This approach explains the difference in the location of differentiating buds along the shoot in different years. Induction is not sufficient to ensure the development of flower buds. Summer induction could be looked upon as the conditioning of the buds to respond to the winter conditions which are obligatory for the final initiation and subsequent reproductive differentiation of the buds. This second stimulus in the winter is mostly temperature-dependent and controlled by the amount of chilling and its sequence (Hartmann and Whisler 1975, Denney and MacEachern 1983). Thus, the chilling conditions, although not the initial inducers of floral differentiation, are responsible for its expression. It could be concluded that the amount of flower bud differentiation of each tree is a function of the interaction between the intensity of the summer (mostly endogenously-governed) factors and the winter (mostly environmental) conditions involving mainly the amount and timing of chilling hours.

The timing of winter chilling is not critical as long as it is not broken by a high temperature period before a minimum amount of chilling has been received by the buds. Interruption of winter chilling by a period of intermediate temperature (up to 18ºC) seems to have no negative influence on the chilling effect. Chilling temperatures of 5-7ºC as part of a daily temperature cycle are most efficient in activating floral induced buds. Continuous chilling temperatures seem to be less effective than those which are part of a daily high/low temperature cycle, (Badr and Hartmann 1971) although a constant temperature of 12ºC was also shown to be active in enhancing flowering (Hartmann and Whisler 1975). The high responsiveness of olive buds to a temperature cycle in addition to the inductive response of constant 12ºC, might explain the high flower bud differentiation and yield in certain warm regions with very little actual chilling. The difference between day and night temperatures in the winter in some regions and a rather uniform temperature around 12ºC in others seem enough to allow the expression of summer induction for differentiation in the spring.

All the same, it should be noted that in those regions with such special floral inductive conditions, flower bud differentiation in cooler years is considerably higher than in warmer ones. Furthermore, in unusually warm years, flower bud differentiation is greatly inhibited and the yield extremely low (Bet Shean, temperature and yield records for 40 years).

The role of leaves on floral induction

The presence of leaves is critical for the induction of flower bud differentiation, particularly for the secondary winter stimulus described. Removal of the leaves in the early winter inhibited nearly all flower bud differentiation. Removal of the leaves from mid-January onwards did not have such an inhibiting effect (Hackett and Hartmann 1964). In most cases, by the end of January or first week of February, leaf removal had no further effect on the number of differentiating buds. Thus it was concluded that the responsive period for winter floral stimulation is mid-January. This timing, however, is not rigid and may vary according to the growing area. From these old experiments, which should be repeated and subjected to modern statistical analysis, it could be concluded that the signal for winter induction comes from the leaves. The leaf removal effect cannot be explained on the basis of nutritional stress caused by the removal of the photosynthetic source because, below 10ºC, there is no active photosynthesis and the response is drastic, rapid and only due to specific timing. Thus the leaves are considered the source for a signal leading to the onset of the differentiation process.

It has been shown by the girdling experiments (Hackett and Hartmann 1964) that this signal can be transported in the tree mainly within the branch but also between neighbouring branches. However, the chilling effect even on shoots with intact leaves is restricted to the chilled buds only. Chilled and non-chilled normal shoots on the same plant responded independently to the environmental conditions they were exposed to. The efficiency of the leaves as the source for the induction signal is very high. It has been shown in these experiments that the removal of 90% of the leaf area from each leaf did not affect the level of bud differentiation. This has recently been questioned independently in the work of Harshemesh and Tombesi (personal communication).

The effect of light on bud differentiation and growth

The effect of leaves during the winter is light-dependent. Darkening the leaves during the winter period will result in a similar differentiation inhibition to leaf removal. Furthermore, light intensity also seems to be critical for the floral induction process (Tombesi and Standardi 1977). Dense and shaded regions of olive trees differentiate considerably fewer flower buds than well-lit parts. This cannot be explained on the basis of lower photosynthetic activity in the shaded regions because of the rather rapid translocation of photosynthates in the tree. Furthermore, analytical studies have shown (Stutte and Martin 1986a, Klein and Lavee 1977) that neither the level of carbohydrates nor organic nitrogen reserves in the tree are responsible for the high or low differentiation potential of the olive tree in different years. The effect of high light intensities on increasing flower bud differentiation and fruiting is the basis for pruning methods and planting distances that have been designed to increase light penetration between and into the trees and thus increase the active fruit-bearing area.

The mode of action that requires high light intensity for the floral differentiation of olive buds is not yet clear. However, the high sensitivity of the olive tree to shading is well known in practice, causing not only a direct reduction in inflorescence development but also a reduction in fruit set and increased leaf drop.

High light penetration is also needed for growth initiation of all olive buds (Tombesi and Standardi 1977). Thus the natural crown of the olive has a dense foliage layer at the crown surface with only a small amount of leaves inside the crown. Although olive leaves can live for 3 years, they usually drop during the second year due to the shade created by the intensively developing outer crown. The decrease in photosynthetic activity due to leaf shading is very rapid. Thus the contribution of old leaves to the productivity and development of unpruned trees is relatively small. Enhanced leaf drop and inhibition of bud opening in shaded parts of the tree cause a decline and often drying of the shaded 2-3 year-old branches. This phenomenon is severe in both extensive, slow-growing and intensive, irrigated, vigorous orchards. Shaping and pruning the trees for increased light penetration on an annual or biennial basis is critical for efficient utilization of the trees' fruiting potential.

PHOTOGRAPH 30. The effect of severe pruning for light penetration on renewal growth of irrigated (A + B) and non-irrigated (C) olive trees.

The morphogenetic potential of old olive wood also depends on the degree of light penetration. The main scaffolds of the olive tree rarely develop new branches while shaded by the tree crown. If light is allowed to penetrate the scaffold by appropriate pruning, they can be induced to push out latent buds or morphogenetically activated even at their older, lower parts. This light-induced morphogenetic potential of old olive wood is used in practice to reduce the height of old trees or renew their crown altogether (photograph 30).

FLOWER DEVELOPMENT, VIABILITY AND FRUIT SET

Both the size of the inflorescence and the viability of the flowers are dependent on the fruiting history of the tree, their location on the shoot and environmental conditions. Inflorescences at the proximal and distal ends of the shoot are usually smaller than at the middle. Flowers at the shoot base are smaller and less viable. The number of imperfect flowers is often higher at the distal inflorescences although this has only been noticed in «On» years with a high level of flower bud differentiation. Although the ratio between perfect and imperfect flowers varies greatly from one year to the next, no significant correlation between the amount of perfect flowers and yield has been found (Brooks 1948). The reason and conditions responsible for the varying amount of imperfect flowers is as yet unknown. It has been shown, however, (Hartmann and Panetsos 1962) that water stress during floral development after differentiation might cause significant changes in inflorescence development and flower viability and fruitfulness. Imperfect flowers were shown to abscise earlier than unfertilized perfect flowers (Rapaport and Rallo 1991a). The peak of perfect flower drop was found about 12-15 days after full bloom. Eight days after full bloom, about 20% of the ovaries present on the tree are fertilized. By 18 days, this percentage increases to about 60%. Twenty-five days after full bloom, the number of fruitlets on the tree stabilises and only very little fruit drop occurs thereafter (Extremera et al. 1988, Rapaport and Rallo 1991a, 1991b) .

The main drop of unfertilized ovaries coincides with the onset of expansion of the fertilized ones (Rapaport and Rallo 1991b). The duration of the flowering period depends on the environmental conditions. The effect of climate on the amount of fruit set is highly significant. As discussed earlier, both hot and dry, and cool and wet climates reduce the amount of fruit set to a significant extent.

TABLE 2
THE EFFECT OF FLOWER AND INFLORESCENCE REDUCTION ON FRUIT SET OF THE REMAINING INTACT INFLORESCENCES
(Inflorescences removed or shortened about 10 days before flower opening)

Treatment	Flower set %	Inflorescence with fruit %	Inflorescences with more than one fruit % of total	Inflorescences with more than one fruit % fertile
Control unthinned	2.3	38.0	7.7	25.7
Half inflorescence length	5.1	41.2	10.1	23.1
Half inflorescence number	9.4	62.5	31.6	50.9
LSD at P = 0.05	0.9	4.9	5.2	6.1

Above a critical minimum, the number of flowers per shoot or tree has a relatively small effect on the amount of fruit set and yield. Thinning perfect flowers within the inflorescence had no significant effect on the final fruit number (Rallo and Fernandez-Escobar 1985). On the other hand, in a recent study, we were able to show that the amount of inflorescences per shoot has a major effect on the percentage of fruit set per inflorescence. The removal of 50% of the inflorescences from the shoots prior to flower opening resulted in an 80-90% increase in the number of inflorescences which set fruit on each shoot (Table 2). Furthermore, the percentage of inflorescences with more than one fruit also doubled on shoots which were thinned to half the number of inflorescences. Shoot length, however, had no effect on the relative amount of fruit set. Vigorous, well-developed trees produce a high yield because the longer fruiting shoots bear proportionately many more inflorescences. However, in most cultivars the relative fruit set per inflorescence is the same on long or short shoots. This seems not to be the case with Chemlali in Sfax (Trigui, personal communication). Weaker trees with a short annual growth period also have the same percentage of fruit set. It was clearly shown in the field (data in preparation) that the percentage of fruit set was considerably higher in years with 30-40% of flowering potential than in those reaching the full 85-90% potential. These results corresponded fully with those obtained by manually reducing the number of inflorescences.

It could be concluded, therefore, that the amount of yield is affected to a much greater extent by shoot length than by a reduction in the number of inflorescences per shoot even if this reaches 50%. This constant fruit set per shoot length rather than per flowering intensity may explain the higher production of trees with vigorous annual growth even if the relative amount of inflorescences is smaller than on trees with weaker or shorter annual growth.

After petal drop the ovaries are visible in the sepal cup. In most cultivars they are a light green colour. Within 10 days the fertilized ovaries turn darker green and their growth rate increases. The fertilised ovaries are located arbitrarily on the inflorescence with no preference for any specific location. The number of set fruit per inflorescence is dependent on the cultivar, weather conditions, the number of inflorescences for a given length of annual growth and the uniformity of flowering. The uniformity of flowering in turn is also dependent on a variety of environmental and endogenous factors.

Under normal developmental conditions all the unfertilized ovaries drop, leaving on the tree only the fertilized ones which eventually will develop into normal fruit (Altamura Betti et al. 1982). However, in various cultivars and occasional years, parthenocarpic fruit develops.

It has been suggested that the ovary of the first fertilised flower on each inflorescence is the one which will continue to develop as normal fruit. It is also assumed, although no solid proof is yet available, that the fertilised ovary secretes inhibitors or creates a hormonal balance preventing other flowers on the inflorescence from setting. The development of more than one fruit per inflorescence is explained on the basis of occasional simultaneous setting of more than one flower. The frequency and degree of multiple fruit set per inflorescence is dependent on the cultivar and climatic conditions during bloom.

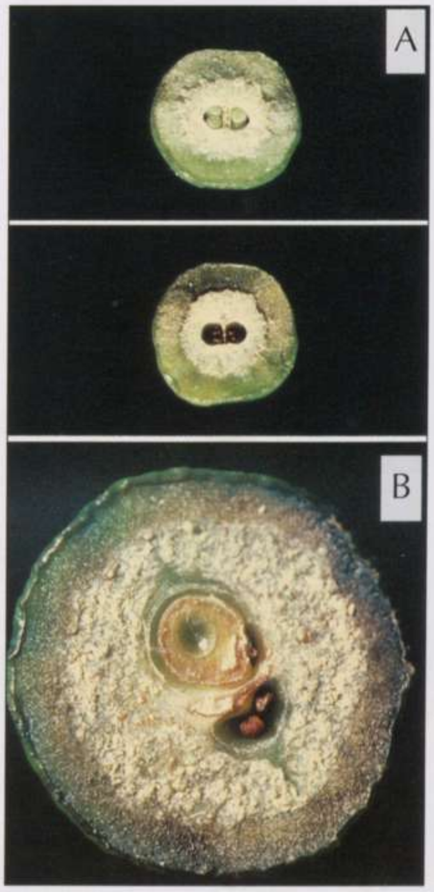
Small parthenocarpic fruits are occasionally found in clusters of many small fruits on inflorescences without any normally developing fertilised fruit. It is

PHOTOGRAPH 31. Different types of parthenocarpic fruit on inflorescences with and without a normal developing fruit.

not clear why in some years parthenocarpic fruits develop and stay on the inflorescence while in others they abscise within 2 weeks. It is clear, however, that the pistils were stimulated to develop. This induction could be triggered by pollination with unviable pollen, inhibition of the pollen tube development in the style, or abnormal development of elements of the ovary. The pathenocarpic fruit which develop as a cluster on the inflorescence remain small and have a light green colour. They do not develop the anthocyanin-based black colour even if they remain on the tree during the whole growing period. These shot berries remain small with a diameter of not more than 2-3 mm and are only rarely found on inflorescences with a normal developing fruit.

Another type of parthenocarpic fruit, larger in size, do not develop in groups of more than 2-4 fruits. They can be found either on the same inflorescence with a normal fruit or on separate inflorescences and are usually the result of normal pollination followed by an abortion of the embryo. The abortion might occur at different stages of fruit development and thus their size could vary in accordance with the time of embryo abortion after pollination (photograph 31).

These parthenocarpic fruits develop the same colour as the normal fruits and have a round shape. The ratio between the stone (endocarp) and the flesh (mesocarp) differs in accordance with the stage at which the embryo aborted. In most cases, the embryo aborts shortly after fertilization and both ovules are equally visible as cylindrical chambers during stone development. At advanced stages, after sclerification of the stone, both ovules remain in the stone as empty tubes (photograph 32). In rare cases, the shrivelled tissue of the aborted embryo is visible in one of the chambers. This type of parthenocarpic fruits develop as normal fruits, accumulate oil but remain round and small and ripen earlier than normal fruits. To date no exogenous treatment with different growth regulators has been able to significantly increase the size of these fruits and thus compensate for the effect of the developing embryo seed on fruit growth and its final size.

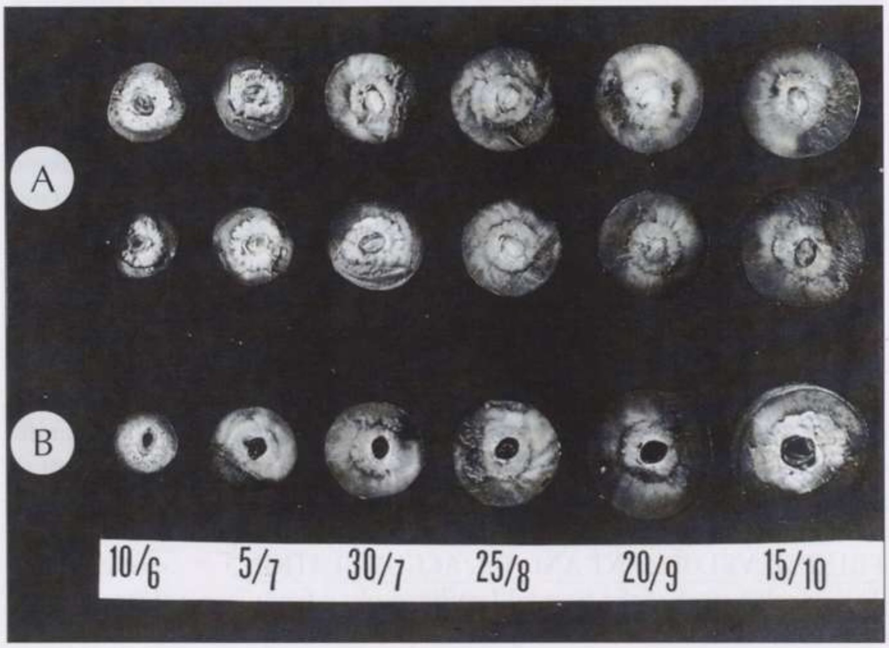


PHOTOGRAPH 32. An advanced stage of a sclerified endocarp of a parthenocarpic fruit with two chambers (A) and a normal pollinated fruit (B).

FRUIT DEVELOPMENT AND OIL ACCUMULATION

The development of the normal fertilized olive fruits is similar to that of most other stone fruits. The sequence of fruit development and maturation was recently reviewed by Tombesi (1994). About 10 days after full bloom, the normal fertilised fruits are distinguishable by their darker colour and in most cases are already at that early stage somewhat larger in size. Twenty days after full bloom the development of one embryo in one of the two carpels is clearly visible (Lavee 1986). The second carpel is pushed aside and gradually closes up so that, about 40 days after full bloom, only one developing embryo in the centre of the endocarp is visible (photograph 33). From fertilisation to full black maturation, 5 developmental stages of the fruit are visible (Hartmann 1949, Shulman and Lavee 1979). These stages are part of a basic double sigmoid growth curve with an initial and final lag stage (figure 6). After fertilisation the initial cell division is rapid but only after about 10-15 days is rapid cell enlargement noticeable. The first rapid growing period (Stage II) mainly involves the growth of the endocarp and, to a smaller extent, of the mesocarp and exocarp. During stage II the fruit consists mainly of the developing endocarp. This stage continues until endocarp sclerification and hardening, usually at the beginning of July. Thereafter, growth of the fruit slows down considerably and stage III of fruit development starts. During the phase of slow growth (Stage III), the embryo and endocarp are reaching their final size, and endocarp hardening (sclerification) is completed. At the end of this period (late July), major enlargement of the mesocarp (flesh) cells starts and thus rapid fruit growth takes place (Stage IV).

During the rapid fruit growth of stage IV, oil biosynthesis and accumulation (lipogenesis) also start. This rapid fruit growth stage ends in the autumn when the fruit starts to change colour. Thereafter fruit growth is markedly slower and various maturation processes take place (Stage V). Oil accumulation also continues during the first part of stage V but, as with fruit growth, at a slower rate. These five stages of fruit growth and development are typical for all cultivars of *O. europaea*. The rate and duration of growth during each stage are specific for each cultivar and growing condition. As the growing curve of each fruit is individual for the various growth stages and particularly the slow Stage III, this is not always notice-



PHOTOGRAPH 33. Changes in the mesocarp-endocarp ratio during the development of normal pollinated olive fruit (A). Embryo abortion might occur at any stage of fruit development (B).

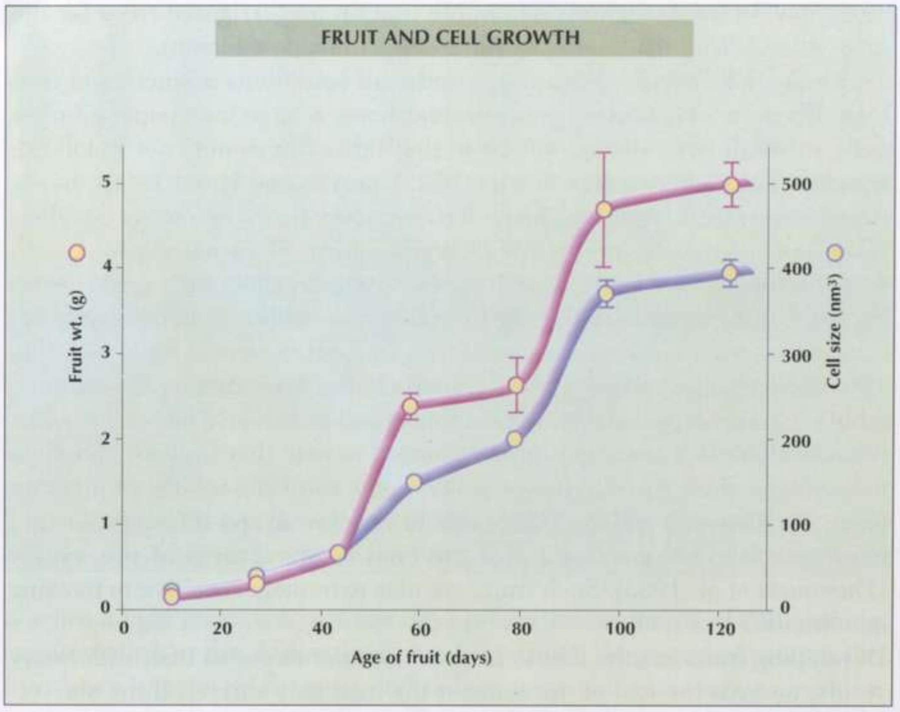


FIGURE 6. The growing curve of olive fruits and mesocarp cells indicating five distinct developmental stages.

able when determined as a mean for a fruit population (Shulman and Lavee 1979).

The length and nature of each stage is affected by environmental conditions. Cell division of most fruit tissues terminates during Stage II except for the embryo in which cell division terminates at the beginning of Stage III. All subsequent growth of the fruit is due to cell enlargement. Thus stress conditions at the early stages of fruit development reducing the rate of cell division cause a reduction in fruit size even if the stress is removed at the later stages of fruit development.

On the other hand, during the first active growing period of the fruit (Stage II), the main developing tissue is the endocarp. In the second half of that period, the endocarp is responsible for up to 80% of the fruit volume. Thus, a period of water stress during late Stage II results in a relatively small stone, leading potentially to a favourable flesh-to-stone ratio at maturation. The actual fruit size is mainly determined during stage IV when the mesocarp and exocarp (fruit flesh) are developing rapidly. Studies of complementary irrigation showed that application of even a small amount of water in August during growing stage IV had a major effect on final fruit size and oil accumulation (Lavee et al. 1990). In most cases, earlier water application had very little effect on fruit size and oil content in comparison with non-irrigated olives (Elant 1956, Spiegel 1955). Furthermore, in some studies, a single irrigation during June or early July even caused a reduction in fruit size (Samish and Spiegel 1961). This reduction in fruit size was due to enhancement of the vegetative growth of the shoots which at that early stage are competing with the development of the fruits. As mentioned earlier, growing conditions such as relative water availability and fruit load do not affect the nature of the fruit's growth curve but do affect the growth rate and thus the size of the fruit (Agabbio 1977). Non-irrigated trees growing on shallow soils are most sensitive to water stress, particularly in «On» years with a heavy fruit load. The size of fruits in a given cultivar on irrigated trees may, in warm regions, be double that on non-irrigated trees for the same relative fruit load (number of fruits per unit shoot length).

Fruit size and time of maturation is under all conditions a function of fruit load. Even under intensive growing conditions, a large fruit population results in small fruit size, so much so that table olives may not reach the standard for marketing (Hartmann 1952, Garoyan and Horel 1980). In extreme cases, fruit might not reach harvesting maturity before its development halts in the winter due to low temperatures. This extreme situation can be overcome by applying a fruitlet thinning treatment (Drobish 1930). Fruit thinning to reduce the fruit number was shown to compensate for those removed in size of the remaining fruits (Lavee and Spiegel 1958, 1967; Martin et al. 1980). Thus a good thinning treatment in intensive table olive orchards does not reduce total yield but clearly increases quality and enhances maturation. It is important to note that fruit which enters the winter before ripening stays at that stage until the weather warms up again the following spring. This is due to very low evapo-transpiration and conductivity in the wood under the cool temperatures of the winter (Thompson et al. 1983). Such fruits are also extremely sensitive to freezing conditions.

Developing fruits are the first to respond to water stress so that, with heavy yields, towards the end of the summer the fruit may shrivel. If the shrivelling is not too severe it is reversible and after the first rain or irrigation the fruits regain their turgor. Thus, following agricultural tradition, in many regions olives are never harvested before the first rain in the fall regardless of the maturity state of the fruit. Although in most cases the fruit recovers from shrivelling, this has a marked negative effect on fruit development as during the moisture stress the metabolism is inhibited and both fruit growth and oil accumulation are halted (Lavee 1986).

The consistency of the fruit's flesh is cultivar-dependent. Large differences in mesocarp cell wall thickness were recorded and thus flesh softness between cultivars is very different. Olive cultivars divide into free, semi-free and cling stone cultivars. It is important to select free stone cultivars for table consumption.

The form of the olive stone is typical for each cultivar and closely related to fruit form. Furthermore, the morphology of the stone is a useful and reliable tool for characterizing and identifying olive cultivars (Barranco and Rallo 1984). This characterization is based both on stone shape and the structure of its surface.

The epidermis of the olive fruit has neither multicellular plates nor stomata like the leaves, although stomata have been reported on the pistil. The «white spots» typical for each cultivar are regions with cavities below the epidermis that are not connected to the mesocarp (Morettini 1972). There are no lenticels or other openings in the epidermis of the olive fruit. The attachment force of olive fruits to the shoots reduces gradually with maturation and the sequence and degree of this reduction is specific for each cultivar and fruit load.

FRUIT MATURATION

Maturation of the olive fruit is difficult to define so there are no clear-cut, objective standards for maturation. The beginning of maturation can be defined as the stage when the chlorophyll content of the fruit tissue begins to decline. The term 'green maturation' refers to the stage when the whole fruit

PHOTOGRAPH 34. Different coloration pattern during maturation in fruit of two olive cultivars. A- cv. Santa Caterina. B- cv. Hallili.

reaches a light green colour a few days before the beginning of anthocyanin accumulation or the dark coloration of the fruits. At green maturation the fruit loses some of its firmness and in free stone cultivars the stone can be pushed out by pressing the fruit. The level of oil content is not a reliable marker for maturation as at this stage there is still active oil accumulation. Chemically, olive fruit maturation is linked with a reduction in the sugar content of the fruits and the accumulation of various aroma compounds, particularly from the high alcohol and terpene groups. Sugar alcohols and particularly mannitol play an important role in metabolite translocation in the olive (Fernandez-Diaz 1971, Tombesi 1994).

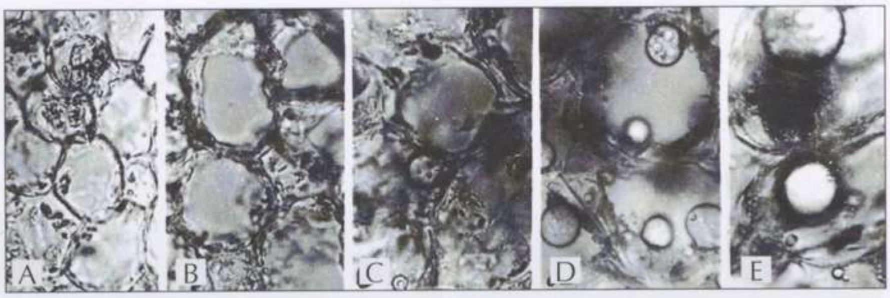
We have recently shown (Lavee and Wodner 1991) that the end of external colour changes is a significant stage in olive fruit maturation, particularly in relation to oil accumulation which is markedly slower after this stage.

Fruit coloration in each cultivar has a typical genetically-determined pattern (Cantarelli 1962). Anthocyanin biosynthesis starts in the epidermal cells, either at the distal or proximal end of the fruits, uniformly for all the fruit of each cultivar. The development of anthocyanin continues in the epidermal cells either upwards or downwards along the fruit. At a later stage, anthocyanin accumulates following the same pattern in the mesocarp (photograph 34). In some cultivars the exocarp and mesocarp lose all the chlorophyll before anthocyanin accumulation starts while in others coloration begins while these tissues are still green.

The determination of black maturation is also difficult as the colour continues to accumulate in the flesh after all the fruit surface (epidermis) is already black.

The non-uniform maturation stage of the black fruit is critical for the preparation of quality products for table consumption but it is also difficult to determine the optimum time for harvesting olives for crushing from the economic point of view. Towards the end of fruit development, the black fruit loses water and at the same time starts a partial breakdown of the oleuropein (Amiot 1986, Shasha and Leibowitz 1948). When most of the water is lost, the fruit also loses its bitterness and can be eaten as it is.

The whole process of olive fruit maturation has a unique pattern. Although ethylene evolution from the fruits increases with maturation, application of



PHOTOGRAPH 35. Distribution of oil droplets in olive mesocarp cell during fruit development of irrigated Manzanillo olive fruits. Magnification x 400. A,B,C,D,E represent cells of fruits 26, 44, 58, 78 and 96 days after fruit set respectively (oil accumulation starts at stage C).

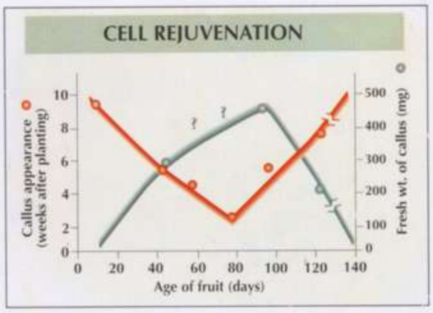


FIGURE 7. Rejuvenation potential of mesocarp cells in vitro at different stages of fruit development. Callus growth was measured 6 weeks after initiation.

ethephon has little effect on ripening (Rugini and Fontanazza 1982). Furthermore, application of ethephon to detached fruits even inhibits anthocyanin biosynthesis (Shulman et al. 1974) whereas cytokinins and some auxins enhance anthocyanin accumulation in 'green' harvested fruits (Shulman and Lavee 1971, 1973). It should also be mentioned that the olive is one of the few fruits known in which the endogenous level of cytokinins increases with maturation (Shulman and Lavee 1976). The endogenous gibberellin level in olive fruit drops during maturation as it does in most drupe fruits (Shulman and Lavee 1980) and reaches very low levels at the time of black maturation. The potential amount of oil accumulating in the fruit at maturation or harvest is, in the broad sense, determined by the cultivar but it varies greatly depending on growing conditions, age, climate and, to a lesser extent, fruit load. Oil accumulation starts in all cultivars shortly after the beginning of growth stage IV so takes place parallel to the active growth of the pericarp cells. Small oil droplets are secreted at the ends of the endoplasmatic reticulum (Lavee 1977). These droplets then fuse to form larger drops which are pushed towards the vacuole and slowly take up some of its place (photograph 35) . When the oil droplets are getting larger, the cells lose their ability to rejuvenate under in vitro conditions (figure 7). At that stage the mesocarp cells become a storage organ although the intact cells are still continuing to grow. During the reorganization of the oil droplets in the fruits, the efficiency of mechanical oil extraction varies in accordance with the compartimentation of the oil droplets in the cells.

The pattern of oil accumulation in olive fruits has been studied with many cultivars and in many different locations (Samish and Samish 1961, Hartmann 1949, D'Amore 1978, Fiorino et al. 1981). Different patterns were attributed as typical for different cultivars. These studies, however, were performed for most cultivars separately and under various growing conditions. In a recent study, we showed (Lavee and Wodner 1991) that under uniform, intensive growing conditions the oil accumulation pattern of 15 cultivars tested was the same (figure 8). When no stress developed during the summer, oil accumulation was linear during the active growth of the fruit. This linearity prevails until the end of the external colour change of the fruit when the rate of accumulation slows down. The daily increase during the linear oil accumulation period is specific for each cultivar. Thus the difference in oil accumulation between cultivars is due to the daily rate of production. This is true also for the same cultivar grown in different locations (figure 9). These results also indicate that the optimal harvest date for all intensively grown cultivars for oil extraction is phenologically uniform at the end of the external colour change.

The linearity of oil accumulation changes if the trees are grown under limiting conditions and there are stress periods during fruit growth (figure 10).

This is the case for most non-irrigated olive orchards for oil extraction in the Mediterranean basin. Therefore the determination of harvest time must take into account the response of each cultivar to stress conditions.

The level of variation of oil accumulation from linearity indicates for each cultivar the severeness of the stress period or periods. On the other hand this variation indicates the degree of sensitivity to stress of different cultivars grown under the same environmental conditions.

Economically, the optimal harvest time for oil extraction is at the end of the linear oil accumulation period (Lavee and Wodner 1991). A delay in harvesting might involve fruit loss and a reduction in quality without a significant gain in oil quantity. The reduction in quality might be related to purity and aroma. Early harvesting, before the end of the linear oil accumulation phase, involves not only loss of quantity but also results frequently in slightly bitter oil which has to be sedimented for a long time. Sensitivity to pre- or post-optimum harvest time differs greatly, depending on the cultivar. In some cultivars, oil characterization and aroma are only slightly affected by the time of harvest while in others marked differences and off tastes occur. The basic composition of the fatty acids in the oil is considerably less affected by the state of maturation than by the cultivar and the environmental growing conditions.

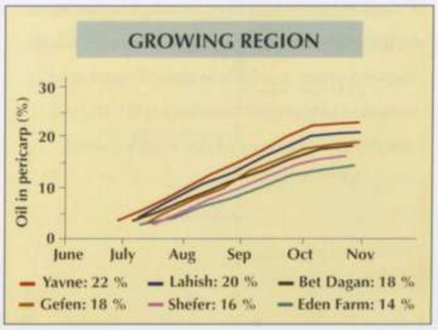


FIGURE 9. The effect of growing region on the pattern and total oil accumulation in the pericarp of intensively grown, irrigated cv. Manzanillo olives. (Location and final oil content in 1984.

1. Yavne 22%,
2. Lahish 20%,
3. Bet Dagan 18%,
4. Gefen 18%,
5. Shefer 16%,
6. Eden farm 14%. SE did not exceed 1.8% of the mean in any of the samples).

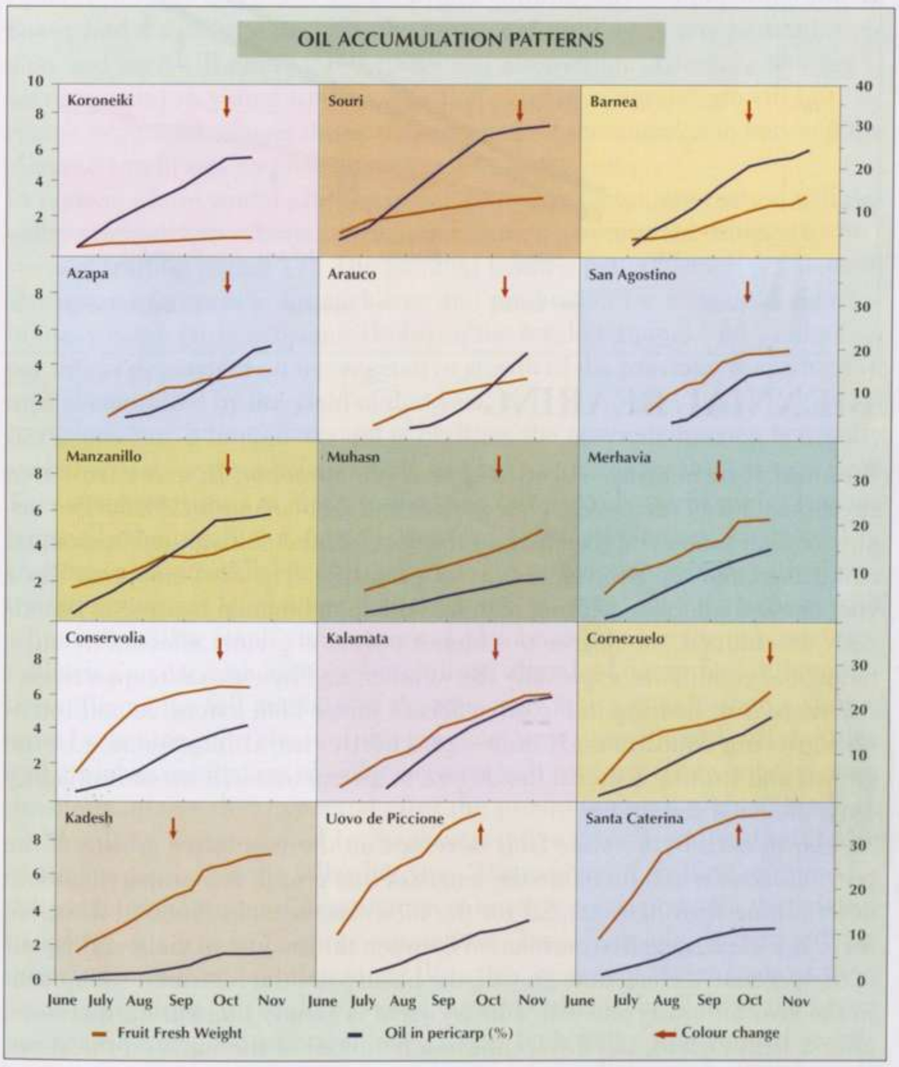
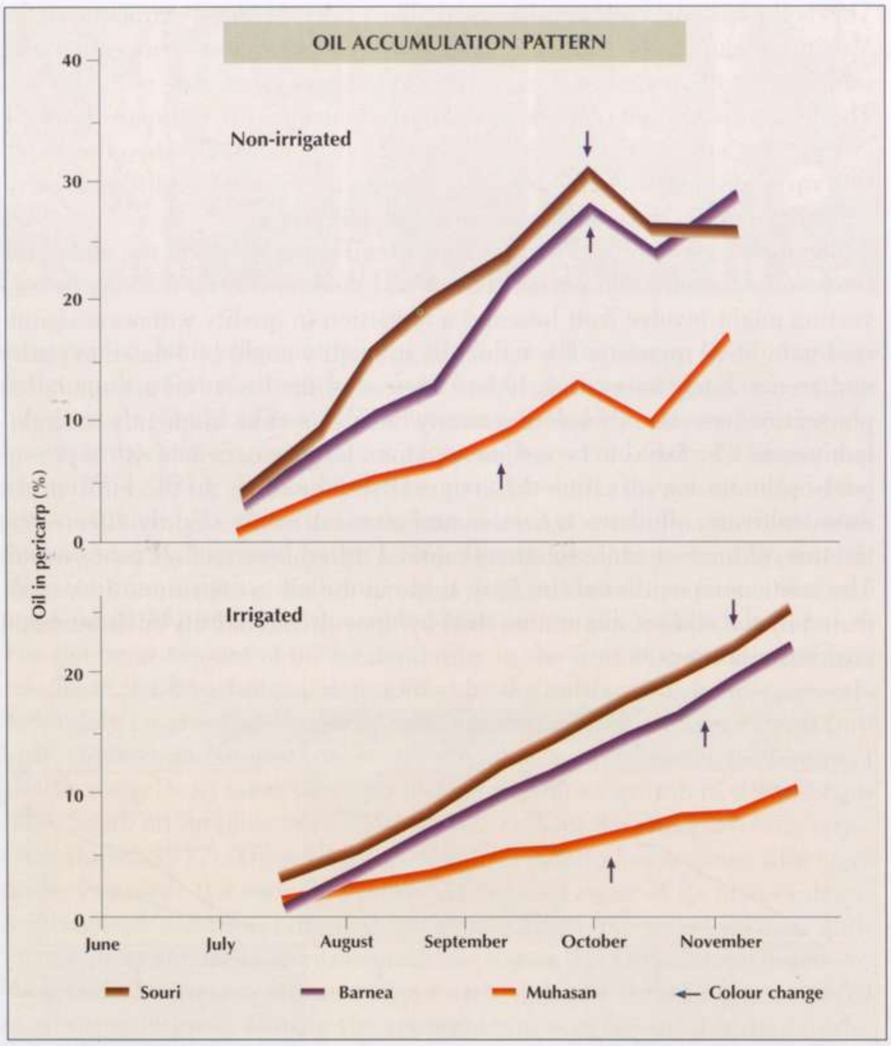


FIGURE 8. Oil accumulation pattern in 15 different high and low oil-containing olive cultivars under irrigated conditions in comparison to fruit growth.

FIGURE 10. The pattern of oil accumulation in the pericarp of three olive cultivars under non-irrigated, partially water-stressed and irrigated unstressed conditions (SE did not exceed 2.1% of any of the mean values).



BIENNIAL BEARING

Biennial fruit bearing is a widespread phenomenon in many fruit tree species and was reviewed by Monselise and Goldschmidt (1982). The degree of alternation is dependent on the species, the cultivar, environmental conditions and the fruiting history of each tree. The *olea europaea* has a very marked alternate bearing pattern. Although biennial bearing is genetically determined, the degree to which it occurs is greatly affected by environmental conditions, especially the weather, and by cultivation practices.
Alternate fruit bearing in the olive occurs under both extensive and intensive growing conditions. If there is no horticultural interference in the growth and fruiting pattern, the degree of alternation will be controlled by environmental conditions.
As shown earlier, the olive fruit develops on the vegetative growth of the previous season and therefore the length of that growth is a primary factor in determining fruiting potential for the following season. Since in the olive there is a clear, negative correlation between the amount of yield and vigour of the vegetative elongation growth, the basic potential for fruit development in the year following one with a heavy yield is greatly limited. Furthermore, after a heavy yield, the differentiation potential of the buds on the short,

rather inhibited shoots, is usually low. Thus shoots of the same length will develop, in most cases, considerably more inflorescences after an «off» year than after an «on» year. The viability of the flowers on the inflorescences also differs according to the fruiting history of the tree. The percentage of fruit set is considerably lower after an «on» year than after the «off» one, whether based on flower or inflorescence number. In some cases, the alternation in yield is less conspicuous than the alternation in fruit number. This phenomenon is based on the close link between the number of fruits and their size (Drobish 1930, Lavee and Spiegel 1958). A smaller number of fruits per tree will result in larger fruits and thus the degree of alternation might be lower. The relation between fruit number and size is not only dependent on the quantity of fruits but also on their distribution. Thus the relative fruit load per shoot is of major importance for the regulation of fruiting and the control of alternate bearing. The trends and degree of alternation depend on the interaction between a large number of external and endogenous factors.

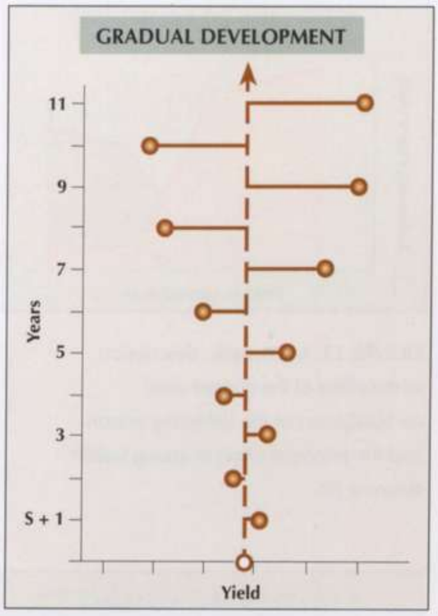


FIGURE 11. A schematic description of the gradual development of alternate bearing under non-limiting environmental conditions.

EXOGENOUS FACTORS – CLIMATIC AND CULTIVATION EFFECTS

Although the alternate bearing of *Olea europaea* is genetically determined, climatic conditions can affect it considerably (Hackett and Hartmann 1967, Lavee 1989). As discussed above, winter chilling plays an important role in flower bud differentiation, thus the amount of chilling in any particular region and year will effect the dynamics of alternation. Alternate bearing is less apparent in young trees due to their vigorous annual growth but becomes more marked over the years as a result of the interaction between the climatic conditions and the fruiting history of the trees.

In regions where winter chilling is not a limiting factor, alternation will develop gradually in relation to the annual increase in yield during the first years of fruiting (figure 11). The biennial bearing pattern which develops in this manner is specific for each tree and production for a single orchard is in many cases fairly constant. However, the level of annual fruit production per tree is dependent on the vegetative growth of the previous year which in turn is controlled by the yield of that year.

In regions with a limited amount of chilling, the alternate bearing is usually synchronised for the whole orchard and in most cases for the entire region. This synchronisation of alternate bearing in relatively warm winter regions is usually the result of a single event leading to full alternation (figure 12). In most cases, insufficient chilling starts the alternation pattern with a winter differentiation level lower than the trees' potential. In such regions with a limited chilling level, alternation can also be induced in the opposite way. Following a year with high winter chilling, abundant flower bud differentiation utilizing the full potential of the trees may take place. In such a spring, most buds along the shoot of the previous year's growth will differentiate and a higher percentage of inflorescences will set fruit. Thus, a heavy crop develops, above that expected after the previous year's yield. This high yield will be accompanied by weak vegetative growth and will minimise fruiting potential for the following year. The amount of chilling required for the induction of winter differentiation is linearly correlated with the relative fruit load of a tree in the previous season. Trees with a high yield will require more chilling to differentiate the same amount of flower buds as trees bearing less fruit. It should be noted, however, that if the yield of the previous season exceeded a critical level, flower buds will not be formed or only

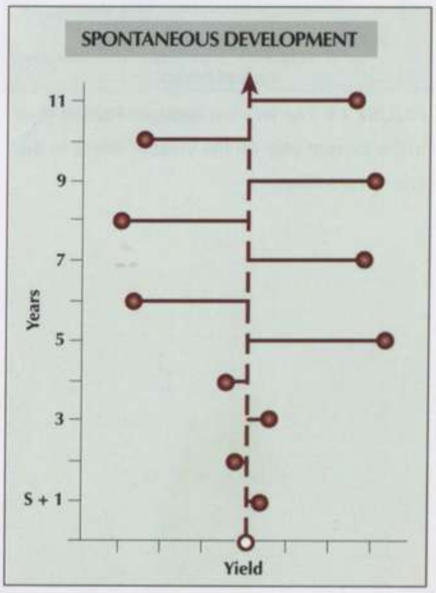


FIGURE 12. Spontaneous development of alternate bearing in olives due to single limiting environmental period before the 5th recorded year.

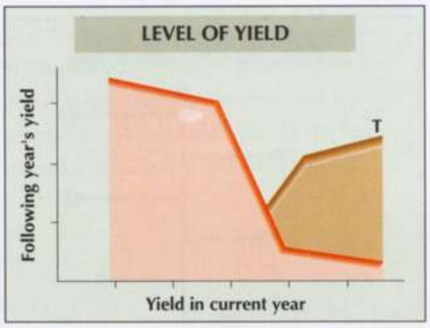


FIGURE 13. A schematic description of the effect of the current yield on fruitfulness in the following season and the principal effect of young fruitlet thinning (T).

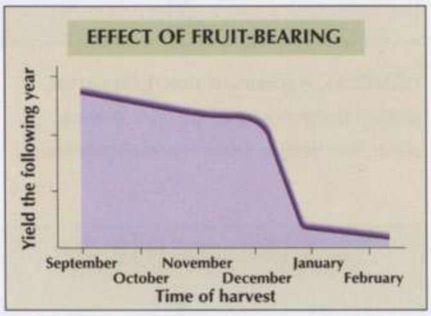


FIGURE 14. The relation between harvest time in the current year on the yield of olives in the following season.

at a low level, regardless of the amount of chilling. The flowers which develop under such conditions are in most cases of low viability and do not set fruit.

Alternate bearing is found equally in non-irrigated and irrigated trees. The same response to climatic effects applies under both types of conditions. Intensification of the orchard by irrigation and controlled nutrition considerably increases the mean level of fruit production. However, without specific horticultural interference, alternation is still marked although on a higher total yield level.

As any level of water application, from a single complementary irrigation to full fertigation, involves an increase in yield it may, on the one hand, induce alternation when first applied but, on the other hand, could be used as an additional tool to reduce it. Although alternation is a general phenomenon of the olive, the degree of alternation is dependent on climatic and cultural conditions as well as on specific treatments in the orchard.

EFFECT OF YIELD AND GROWTH RATE

The current amount of yield is a major factor determining the degree of differentiation and fruit set in the following one (figure 13). The level of yield in the current year has a dual effect on the following year's fruiting ability. Firstly, it controls the mechanisms of the developing fruit on the level of induction and the differentiation ability of the buds. Secondly, it indirectly controls the vegetative growth intensity of the shoots carrying the fruit in the following year. It is obvious that a limitation of the vegetative growth rate will result in shorter shoots with fewer buds and thus a lower potential number of inflorescences for the next fruiting year. On the other hand, trees with vigorous vegetative growth due to a low current yield develop long vegetative shoots and a large number of buds for potential inflorescence differentiation, environmental conditions permitting.

The relation between vegetative vigour and alternate bearing can partially explain the small degree of alternation in young trees. During the first years of development after planting the tree, the relatively small number of vegetative growing points are powerful sources of metabolites and thus annual growth is strong and long. Yield, however, is still limited due to the small volume of the tree and long internodes and, therefore, a smaller number of buds on the vigorous shoots. Yield increases annually during the first years of tree development. Only after the trees reach their full canopy size, individual apex growth rate is reduced and the relative competition of the developing fruits increases. On the other hand, very vigorous trees or shoots and particularly the growth on scaffolds after heavy pruning continue to be vegetative for at least one additional year. Only after that is the balance between vegetative growth vigour and fruiting reactivated.

Time of harvest has a major effect on fruiting ability in the following year (figure 14) although this is limited to relatively late harvesting (Dec. or Jan.). Harvest time until this date has only a relatively small effect on the next yield. Under intensive growing conditions, trees with a very high yield will have a small yield the following year, even when considerable vegetative growth occurs parallel to the high yield. In most cases, inflorescences will not be formed and, if they are formed due to favourable winter conditions, such flowers usually do not set fruit or only very few of them do. This indicates that either the amount of reserve metabolites or a control mechanism governed by the developing fruits is responsible for the annual fruiting ability of the tree or in some cases the individual scaffolds. It can therefore be asserted that an endogenous control mechanism, which is partially independent of the environmental conditions, governs flower bud induction and differentiation.

METABOLIC REASONS FOR ALTERNATION

Nutritional depletion of the tree during the «On» year was thought to cause unfavourable nutritional conditions for flower bud induction and differentiation. Studies of the nutritional state of «On» and «Off» olive trees were conducted at various places (Stutte and Martin 1986a) but the findings did not show a clear relation either between the mineral or standard organic reserve metabolites and alternation. In various cases, differences in the amount of many nutrients could be found between the leaves of «On» and «Off» trees but these differences were too small to account for alternating fruit production, or were related to the seasonal stage of tree development (Priestley 1977). The marked alternate bearing of the olive cannot therefore be due to nutrient depletion. It seems that alternation is controlled by induction and differentiation inducers and repressors, the production of which is initiated by the developing fruit. The effectiveness of these regulators is determined by environmental conditions, mainly the weather.

Plant growth regulators have been shown to be such signal-producing agents. The nature and intensity of their responses depends on the ratio between them. In many fruit species, an exogenous application of a growth regulator such as cytokinin may induce flower bud induction or differentiation (Mullins, 1980, Grochowska 1963) but this is not possible with olives (Badr and Hartmann 1972). On the other hand, IAA was shown to be taken up and translocated after application (Epstein and Lavee 1977). Furthermore, Epstein (unpublished) has shown that during the winter differentiation period of an «On» year, bound auxin (IAA) was considerably higher in olive leaves than in the «Off» year.

Gibberellic acid has been shown in many species, including the olive, to reduce flower bud differentiation (photograph 36). The effective time is specific for each species. In the olive, the strongest inhibition was found after a winter application but an inhibitory effect was also found after summer and autumn applications (Badr et al. 1970, Lavee and Haskal 1993).

PHOTOGRAPH 36. The effect of a winter application of gibberellic acid on the flowering of cv. Manzanillo olive trees. Left- scaffold untreated. Right- treated with 1000 mg/l GA.

The anti-gibberellin paclobutrazol was shown to be effective in reducing growth and increasing fruit production (Porlingis and Voyiatzis 1986, Lavee and Haskal 1993) but the effect of paclobutrazol in the olive is more complex than in most other fruit species and lack of response was also reported.

Higher vegetative vigour and low productivity are associated with high gibberellic acid levels. Thus the relation of this regulator to alternate bearing cannot be a simple one as, in the «On» year, growth is retarded so the GA level should be low at the time of differentiation. Badr et al. (1970b) have shown that endogenous gibberellins vary during different stages of bud development. In a recent study, Ben Tal (unpublished) has shown that different Gibberellins are detectable at different stages of bud development. This was particularly the case when buds from «On» and «Off» year trees were compared. It seems, therefore, that specific gibberellins might be the messengers for the signal inducing vegetative or reproductive bud differentiation and the origin of such signals has been the subject of research by various workers.

Leaves have been shown to be essential for flower bud induction. Defoliation of olive shoots at critical periods resulted in lack of, or greatly reduced, differentiation (Hackett and Hartmann 1964). The removal of leaves causes not only the reduction of photosynthesis and thus of the level of carbohydrates but also the elimination of the source for specific substances with regulatory properties such as Naringenin in peaches (Erez and Lavee 1969), Phlorizin in apples and oleuropein in the olive (Bongi 1986).

Long-term studies over the last 10 years have shown that the level of some specific phenolic acids and particularly chlorogenic acid (CHA) in the leaves was related to the load of fruit on the trees (Lavee and Avidan 1981). A quantitative determination of CHA by HPLC (Epstein et al. 1987) showed that, in «On» years, the level of CHA in the leaves is high while, in «Off» years, it is low (figure 15). Chlorogenic acid was found (Lavee and Avidan 1982) to be active in inducing olive tissue growth in vitro as with IAA (photograph 37). Even more significantly, when CHA is injected into the tree (photograph 38), it significantly reduces the amount of flower bud differentiation (Table 3). Some reduction was also found with other phenolic acids of the cinnamic acid-lignin pathway but to a much smaller extent (Lavee et al. 1986). This injection system was also used by Navarro et al. (1992) in Spain for studying regulating chemicals in olive trees.

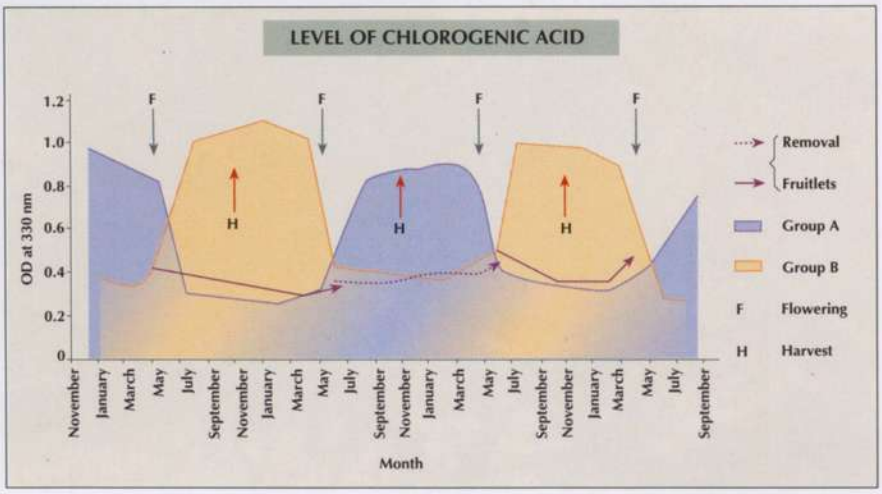
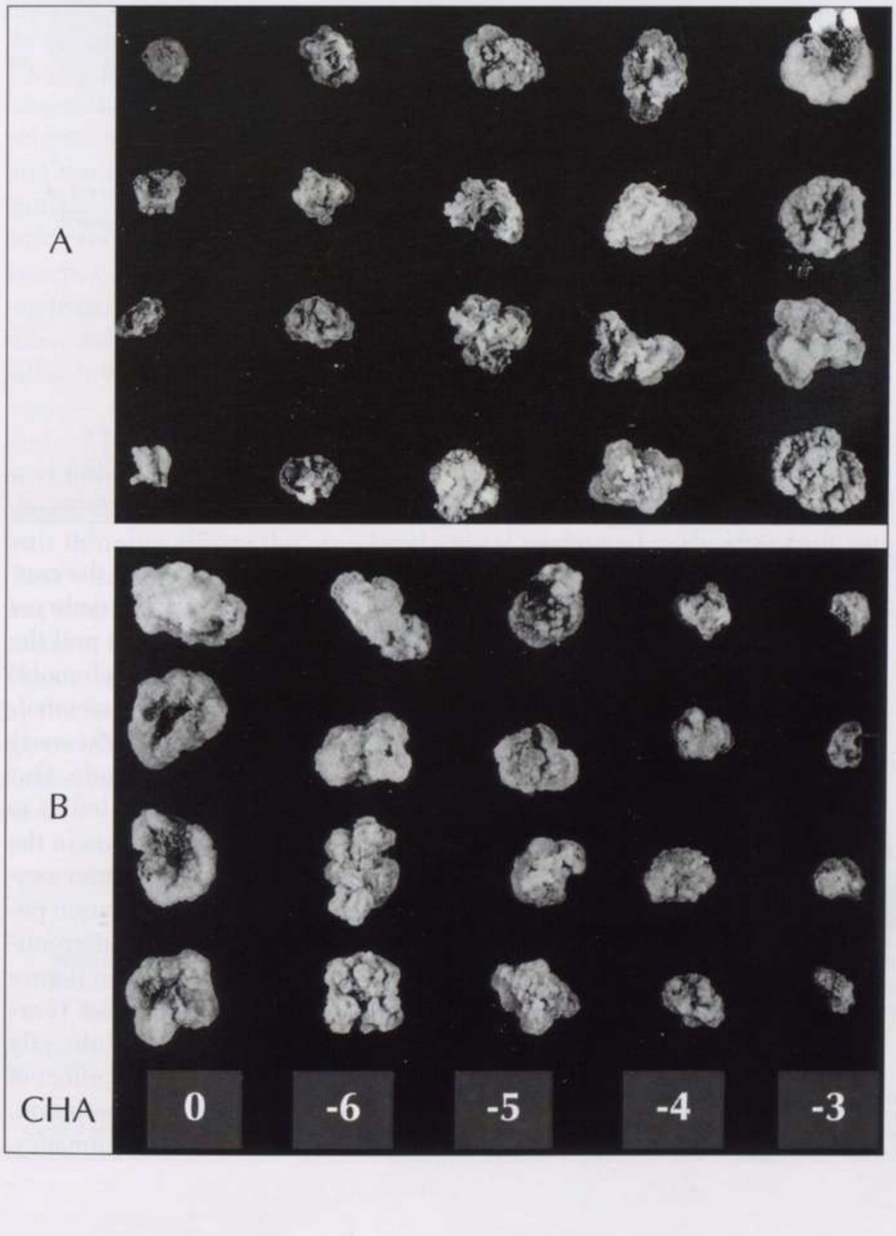


FIGURE 15. The change in level of chlorogenic acid in the leaves of «On» and «Off» olive trees.

It has been shown that the accumulation of CHA in the leaves is controlled by the developing fruit on the tree. Removal of the young fruitlets from the trees after set avoids the accumulation of CHA in the leaves and enables good differentiation and bloom in the following season (figure 16). This is not the case when the fruit in the «On» year is removed later (at pit hardening) when the level of CHA in the leaves is already high (Lavee et al. 1986). Navarro et al. (1990) indicated that buds on «Off» trees contained higher levels of RNA in July-August than buds of the same age on «On» trees and statistical calculations also showed that the former were somewhat larger.
Thus a change in leaf metabolism is involved in the control of fruit bud differentiation. This change is induced by the young developing fruits on the tree which also provide growth regulators such as auxins and gibberellins affecting flower bud differentiation. Hormonal diffusates from developing olive fruits were described by Hartmann et al. in 1967 and it has been shown (Stutte and Martin 1986b) that if the embryos in 6-week-old olive fruits are killed, alternation is minimised although the fruits themselves continue to develop on the trees. The effect of fruit thinning in «On» years



PHOTOGRAPH 37. The effect of chlorogenic acid (CHA) and NAA on in vitro callus growth in cv. Manzanillo olives. A- No NAA. B- 1.0 mg/l NAA.

PHOTOGRAPH 38. A low pressure injection system (A) developed for introducing chemicals into the transpiration stream of growing olive trees. After injection the port is sealed off (B).

TABLE 3
THE EFFECT OF WINTER AND SPRING APPLICATIONS OF EXOGENOUS CHLOROGENIC ACID (CHA) ON FLOWER BUD DIFFERENTIATION AND FRUIT SET ON CV. MANZANILLO TREES.
(CHA was pressure injected into scaffolds)

Treatment of branch	Inflorescences number per Branch	Inflorescences percent of control	Fruit set %	Fruitlets Number per branch	Fruitlets percent of control
4 injections Dec. 10 - Feb. 10					
Untreated	227	100	26	59	100
CHA injected	118	52	23	27	46
3 injections Feb. 15 - Mar. 15					
Untreated	220	100	28	62	100
CHA injected	215	98	30	65	105
MSE	10	-	-	4	-

on the level of production the following year results from reducing the controlling effect of induction and differentiation in the developing embryos and not from competition for nutrients between the growing fruits and the differentiating buds. This involvement of the accumulation of phenolic acids in the leaves is of particular interest as it causes a long-term metabolic change which explains the effect of the developing embryos in the early summer on late winter differentiation of the summer-induced buds. Our work on alternate bearing over the last 15 years (Lavee 1989) has led us to suggest that the initial induction for flower bud differentiation occurs in the early summer, as it does for many other fruit tree species. The winter season, which was generally considered to be the flower bud differentiation period, should be considered as secondary – it is mainly the organ differentiation period (late winter) based on the primary summer induction (figure 17). This was recently confirmed by injection experiments with GA (Fernandez-Escobar et al. 1992). A study by Rallo and Martin (1991) indirectly also confirmed this approach though they raise the question of the effect of low winter temperatures on the secondary process of bud differentiation. The chilling requirement of the olive, in their view, is due to bud dormancy.

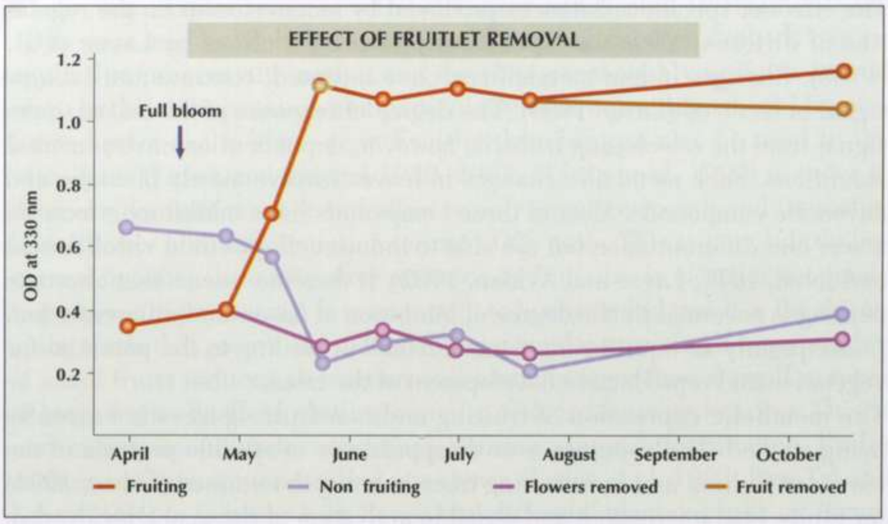


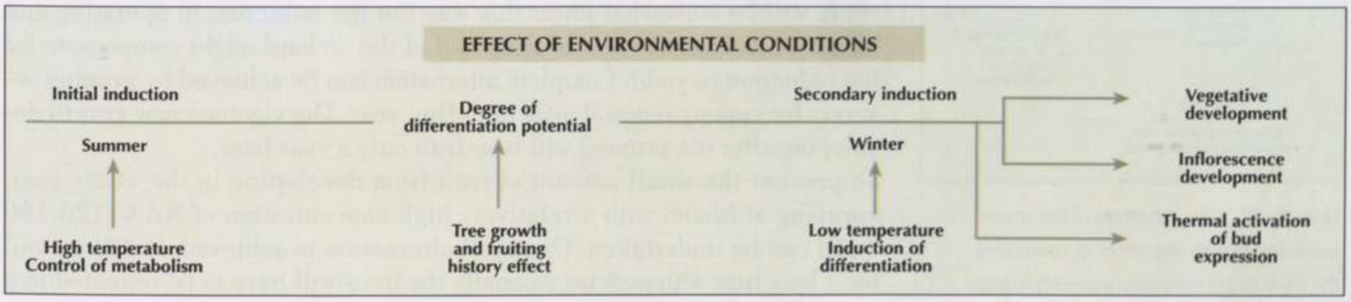
FIGURE 16. The effect of fruitlet removal during and right after set on chlorogenic acid accumulation in the leaves of cv. Manzanillo trees.

This however, is questionable on the basis of data from many studies dealing with olive bud opening under different, controlled-environment conditions.

The involvement of developing embryos in producing diffusable regulating factors that affect both floral initiation and diffusable reproductive organ development was clearly observed in olive inflorescences. It has been shown that the first flowers in the inflorescence to set fruit inhibit, in most olive cultivars, the normal set of additional fruits in the inflorescence. Therefore cultivars with the ability to develop parthenocarpic fruit will often form bunches of such fruit on inflorescences without a fertilized normal developing fruit. Furthermore, the seed kill studies by Stutte and Martin (1986b) showed that only the embryos have an effect on flower bud induction for the following season, regardless of the amount of seedless fruits left on each tree.

Embryo growth in the olive fruit occurs about 6 months or more before the next flower bud differentiation although initial induction, as suggested above, takes place at an early date. However, in highly alternating olives, fruit thinning affects the crop level only if performed early after fruit set (Lavee and Spiegel 1958, Martin et al. 1980). Slightly later fruit removal was ineffective (Lavee and Spiegel-Roy 1967). On the other hand, leaf removal at differentiation time will reduce or prevent flower bud development. Thus it seems that the initial signal for alternate bearing might be received by the leaves which undergo a metabolic alteration, due to the signal from the developing embryos in the fruits, and serve as a storage organ for the information controlling the next flower bud, induction and differentiation periods.

FIGURE 17. A flow diagram of the effect of environmental conditions on the stages leading to reproductive and vegetative development in olive trees.



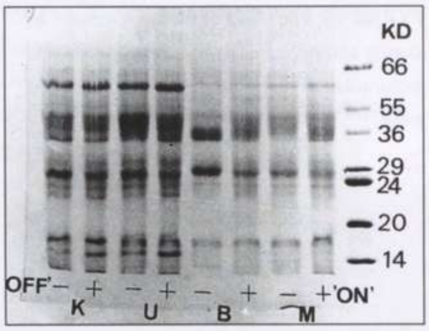


FIGURE 18. Protein distribution in the leaves of «On» (+) and «Off» (-) olive trees from four cultivars. K- Koronaiki, U- Uovo di piccione, B- Barnea, M- Manzanillo. Sampled before harvest on Oct. 23.

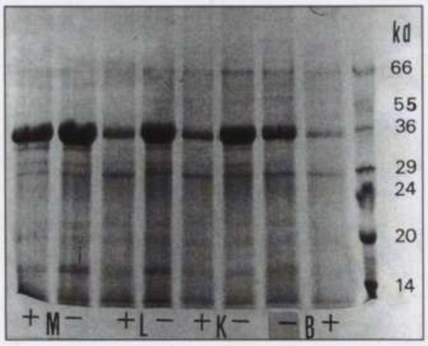


FIGURE 19. Protein distribution in the bark of one-year-old olive shoots from «On» (+) and Off» (-) trees of four cultivars. M- Manzanillo, L- Leccino, K- Koronaiki and B- Barnea. Sampled- July 29th.

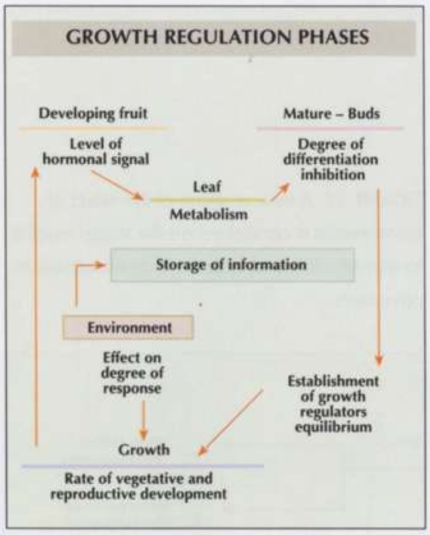


FIGURE 20. A flow diagram of the stages involving growth regulators in controlling the level of alternate bearing in olive trees.

The effect of specific substances produced by mature leaves on the regulation of differentiation was specifically shown for olives by Lavee et al. (1986). Changes in leaf metabolism, once initiated, continue until a new signal is received (Lavee 1989). The degree of response of the leaves to the signal from the developing fruits is, however, dependent on environmental conditions. Such metabolic changes in leaves involve mostly phenolic and flavonolic compounds. Most of these compounds have inhibitory effects on flower bud differentiation but are able to induce cell growth in vitro (Feucht and Johal, 1977; Lavee and Avidan, 1982). It therefore seems that alternate bearing is governed by the degree of inhibition of flower bud differentiation. Consequently an equilibrium is established according to the potential for vegetative and reproductive development of the trees.

The metabolic expression of fruiting and non-fruiting trees is currently being studied. The appearance or disappearance of specific proteins in the leaves of fruiting and non-fruiting trees is being determined (Lavee, 1994) for future characterization and possible activation of the genes involved in the metabolic pathway leading to flower bud differentiation. Differences in the leaf proteins of fruiting and non-fruiting olive trees of various cultivars have been shown (figure 18) as well as more significant differences, particularly of proteins, sizing 16 and 32 kd, in the bark of one-year-old shoots (figure 19). The buds on these shoots are those stimulated for flower development or vegetative growth in the following season. Cytochemical studies of the buds also support the horticultural and physiological findings for early summer induction leading to later flower bud differentiation (Pinney and Polito 1990).

From the information currently available, it is suggested (Lavee 1994) that alternate bearing is initiated by a signal, probably a hormonal signal, diffusing from the developing fruits to the leaves. A metabolic change occurs in the former resulting from the activation of specific genes leading to the production of a differentiation inhibitor at a rate determined by the intensity of the signal and the environmental conditions. The leaf inhibitor (probably phenolic) will determine to what extent buds will undergo a metabolic change leading to flower bud differentiation. This equilibrium between vegetative and reproductive development is based on the previous development and yield of the tree as well as environmental conditions (figure 20).

HORTICULTURAL INTERFERENCE AND METHODOLOGIES TO OFFSET ALTERNATE BEARING

Horticultural means can be used both to enhance and decrease alternate bearing. Complete alternation can be developed and this might be useful in regions where climatic conditions are not a limiting factor for flower bud differentiation. Under such conditions, half the orchard can be induced to bear fruit one year and the other half the next. The combined yield of the two years will be somewhat lower this way but the reduction in operating and labour costs from the non-bearing half of the orchard might compensate for the reduction in yield. Complete alternation can be achieved by pruning severely for canopy renewal after the «On» year. The vigorous new growth developing after the pruning will bear fruit only a year later.

To prevent the small amount of fruit from developing in the «Off» year, spraying at bloom with a relatively high concentration of NAA (120-150 mg/l) can be undertaken. Once full alternation is achieved, it will prevail for a long time although occasionally the trees will have to be retreated in a similar way. Winter spraying with GA (Lavee and Haskal 1994) prior to the «Off» year might also help to eliminate flowering. Similar methods can be applied to prevent alternation and develop a reasonably uniform annual crop. In this case pruning, and particularly severe pruning, should be performed prior to the «On» year. Fruitlet thinning can also be used in the «On» year (Lavee and Spiegel 1958, 1967; Martin et al. 1990) in order to decrease the fruit number and allow more vegetative growth and thereafter better flower bud differentiation for the «Off» year. This is particularly important for intensive table olive orchards as fruit size is of major economic importance in processing. It is important to bear in mind that it is the developing seeds that govern alternation. Thus a yield comprising a large number of small fruits induces alternation considerably more than a small number of large fruits. Scaffold girdling can also reduce alternate bearing. This is particularly useful under conditions limiting winter differentiation. Under such conditions, winter girdling was shown (Lavee et al. 1983; Ben-Tal and Lavee 1984) to increase both flower bud differentiation and fruit set (figure 21). To ensure uniform yearly production, girdling is performed on half the scaffolds on the tree in one year and the other half the next. Thus every scaffold is girdled every second year. Although the best results are achieved by mechanical knife girdling (usually about 10 mm wide), chemical girdling by painting a ring of morphactin dissolved in oil on the scaffold is also possible (Ben-Tal and Lavee 1985). It is important to cover the knife-girdled region tightly with a plastic strip (photograph 39) to prevent wound drying and insect penetration and promote rapid callus development by the wounded tissue.

Winter spraying with a moderate concentration of GA (500 mg/l) prior to the «On» year might also help in reducing the number of inflorescences and thus the fruit load in the «On» year. This will then lead to increased differentiation in the «Off» year.

It should be emphasized that intensification of the orchard by applying irrigation and optimizing nutrition cannot control alternate bearing. More intensive cultivation methods increase both growth and fruit production; alternation, unless reduced artificially, will increase but at a higher total yield level.

As mentioned above, late harvesting also increases alternate bearing. Thus, for annual fruiting, harvest should be performed at the end of colour change and in most regions not later than mid-December.

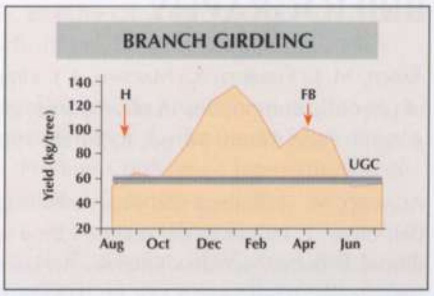


FIGURE 21. The effect of a single girdling of cv. Uovo di piccione scaffolds at various dates on the yield in the following season. H-Harvest, FB-Full bloom, UGC- Ungirdled control.

PHOTOGRAPH 39. Callus development on repeated mechanical knife girdling for about 10 years. Each scaffold is girdled every second year.

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Chapter 3

GENETIC ASPECTS AND PROPAGATION TECHNIQUES FOR INTENSIVE CULTIVATION

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GENETIC ASPECTS AND PROPAGATION TECHNIQUES FOR INTENSIVE CULTIVATION

Giuseppe Fontanazza

GENERAL CHARACTERISTICS

In all olive-growing countries, both within the Mediterranean basin and in countries where this crop has been introduced relatively recently (USA, South America, South Africa), from the agronomic point of view olive cultivation is largely characterised by tradition. The olive has frequently been grown in difficult areas, often at the boundaries of the agricultural environment, because of its capacity to grow on marginal, relatively infertile land, and cultivation is based, above all, on climatic factors. The capacity of the plant to survive through the centuries has preserved ancient olive-growing systems which have rarely been properly renovated.

The social situation in most Mediterranean countries until relatively recently has ensured ample, readily-available manual labour for agriculture which, in turn, has made it possible to maintain traditional olive-growing systems. As of the second half of this century, the problem of having to improve olive-growing systems substantially was tackled with attempts to contain production costs by reducing manual labour through more extensive use of machinery, while increasing mean yield levels. In the initial phase, the technical approaches were based primarily on intensifying existing olive orchards through operations such as increasing plant density, renovation pruning or re-grafting. These operations were supported by the rationalisation of ordinary cultivation practices such as pruning, fertilisation and pest control, all in an effort to optimise production. Olive-growers were guided throughout by the results of research and experimentation obtained mostly after the twenties. At the end of the fifties, in the wake of the major developments that had taken place in the industrial cultivation of fruit, especially in Italy, the first signs appeared that olive-growing too was preparing to change over from extensive, traditional methods to more modern systems based on intensification with new orchards. Despite the positive results which the new cultivation systems provided from the outset, traditional methods continue in all olive-growing countries and especially in those of the Mediterranean basin, mainly for the following reasons:

- the inability of many olive-growers to overcome a psychological attachment, which has created a barrier to the acceptance of technological innovations;
- situations of a political, social and economic nature, such as the fragmentation of property, which make it difficult to set up enterprises of sufficient size;

- complex environmental factors such as climatic, soil and topographic constraints, in which traditional systems are the only ones applicable;
- market factors, where olive-growing is linked to direct consumption so that the possibility of producing oil for the needs of the family or for a restricted local market is a source of satisfaction for the grower, and this satisfaction overrides considerations of adequate remuneration for his work.

In addition to the causes already mentioned to explain the widespread persistence of traditional cultivation practices in most olive-growing countries, there is also an obstacle caused, at least until very recently, by competition from seed oils on the market. By reducing consumption levels of olive oil, such competition has also reduced the motivation for improvements in the sector. In addition, the technological innovations currently available for the effective dissemination of intensive cultivation have for the most part appeared in the last twenty years.

It can therefore be said that there are two types of olive-growing – traditional and modern – in ratios which differ from one country to the other, or from one region to another within the same country, depending on political, economic and social factors which have influenced and continue to influence the changeover from traditional to modern olive-growing practices. Whereas it is conceivable that market forces and the increasing shortage of manual labour will in time cause this ratio to shift, virtually everywhere, towards modern cultivation methods, it is nonetheless unlikely that changes will be so drastic as to bring about the disappearance of traditional olive-growing. This can therefore be expected to continue to a greater or lesser extent, depending on the social, economic and environmental factors prevailing in the various olive-growing regions, where olives may be grown for environmental and landscaping purposes, or for family consumption.

In order to draw a clear distinction between traditional olive-growing, where farming practices depend exclusively on the grower, and marginal olive-growing in which only traditional methods are possible, it is necessary to define the characteristics of marginal olive-growing regions and those of areas that are suitable for modern olive cultivation.

OLIVE-GROWING IN MARGINAL AREAS

Marginal olive-growing regions are those characterised by orchards with scarce production owing to the soil, relief and/or climate. They are usually found to have superficial, rather infertile soils that are excessively stratified or too heavy, as well as steep slopes (over 1:5). The situation is often further complicated by difficult weather conditions with temperatures dropping below zero (-5° to -6°C), low annual rainfall (less than 400 mm) distributed irregularly over the year, and long dry periods, especially during flowering and fruit-bearing.

Any one of these factors implies a state of stress for the olive tree which cannot meet its full productive potential. The existence of steep slopes limits the use of machinery for various cultivation practices, thereby reducing the possibility of generating income. The problem of excessive fragmentation of property may be compounded by a shortage of manual labour and/or deficient infrastructure (roads, processing and marketing centres, etc.).

Typical Mediterranean-type environment suitable for olive-growing. (Photograph by Gianluca Boetti).

In many cases, this type of olive-growing, though of limited economic and agronomic interest, has with time taken on the important role of protecting the soil and conserving the landscape. Furthermore, in some marginal olive-growing areas, typical types of oil with particular quality and organoleptic characteristics may be produced for an elite market. In those places where the conservation of orchards in marginal areas is considered valid for the reasons outlined above, from a technical point of view, the approach pursued is to apply cultural practices to keep the trees in good health. In some cases, productivity is maintained by special pruning to contain the height and volume in order to facilitate cultural care and to improve productive efficiency. The conservation of an olive orchard of this type obviously acquires wider significance than that of a mere farming concern.

In addition to the rationalisation of purely agronomic practices, it is often necessary to take action in connection with the structure of the olive orchard in order to conserve the landscape environment as a whole.

Such actions seldom provide economic benefits for farmers because the costs for both special actions and day-to-day upkeep are high and give zero or below-breakeven revenue.

The high costs also make it impracticable to replant olive orchards in marginal areas whether for production purposes or landscaping.

OLIVE-GROWING IN SUITABLE AREAS

Olive-growing needs sufficient space for the trees to achieve their full potential and so that machinery can be used to cut down cultivation costs and generate profits. Furthermore, the social and market structure must be suitable for processing and marketing the product, so that production levels become even more profitable.

The Mediterranean basin has the ideal climate for olive-growing although the species can adapt to the sub-Mediterranean climate, provided that there are no extreme changes of temperature causing damage or stress. Moreover, minimum temperatures are essential in autumn and winter to guarantee the normal flowering pattern of the species.

In terms of soil conditions, olive trees adapt to different soil types, with the exception of soils with a particularly high clay content (over 45% of clay) because the roots are very sensitive to excessive humidity. Fairly compact, neutral or low alkaline soils that are rich in organic matter are ideal for olive growing. Soils which tend to be clayey can be used for olives only if their structure is not too coarse or if drainage systems are used. From the topographic point of view, slopes should not be greater than 1:5 so that machinery can be used in all cultivation practices.

There must also be sufficient water supplies available to satisfy the requirements of the plants and ensure their survival.

Finally, in a suitable area with optimum growing conditions, olive trees will only reach their full potential if acclimatised cultivars with a high agronomic and commercial value are used, and if appropriate growing and processing systems are applied.

Although many of today's olive orchards are located in suitable areas, they are hampered by traditional structures which limit production capacity and profitability, because of the difficulty of introducing rational mechanisation.

Only in areas which are suited to cultivation in terms of fertility, land characteristics and morphology, exposure, height, weather conditions, water availability, etc. can a modern olive-growing enterprise be set up with intensive use of machinery to enable the species to develop its full productive potential.

While the territory currently used for olive-growing meets these conditions to a large degree, many other areas in traditional olive-growing countries could still be allocated to intensive cultivation of the olive. Attempts to disseminate the olive tree in environments other than the Mediterranean basin, the most ancient home of the olive, have not produced concrete results except in a few areas where cultivation has been consolidated for several centuries, such as the southern part of the United States, Latin America and South Africa. More specifically, attempts made in the last twenty years to grow olives in China, South Korea, Japan, India, Pakistan and Australia have so far yielded only modest results, despite the existence of species similar to the *Olea europaea* in some of these countries. Olive cultivation in a non-Mediterranean context therefore remains relatively limited and confirms that the Mediterranean is the ideal habitat for olive-growing. Consequently it is highly probable, in the medium term at least, that the future of olive-growing in terms of consolidation and development lies primarily in the Mediterranean basin, and in particular in Spain, Italy, Greece

Example of olives in coastal areas. (Photograph by Gianluca Boetti).

and parts of Portugal, Tunisia, Morocco, Algeria and Turkey. In all these countries it is possible to find areas with climates suited to the increase and development of olive-growing.

Moreover, it is safe to predict that, in view of the local environmental and social conditions in North African countries, with limited water resources and a surplus of manual labour, traditional olive-growing will be maintained and in time increased with limited use of mechanisation, whereas in the more socially-developed European countries, and in particular Spain and Italy, olive-growing will be increasingly based on highly innovative production and processing technologies aimed at containing production costs and improving the quantity and quality of production.

TRADITIONAL CULTIVATION

Traditional olive-growing involves a productive structure which, for agronomic reasons (ill-suited cultivars, planting systems, cultivation techniques, age of orchards, etc.), does not allow the species to give maximum yield or makes it impossible to mechanise many of the cultivation operations. This leads to adverse economic results either in terms of production or because of the intensive use of manual labour which ranges between 300 and 400 hours per hectare a year. Olive orchards are often used for other crops as well and therefore are spread over a very wide area. Alternatively, if production is specialised, density per hectare is often low (less than 200 plants) because of the expected growth of the canopy in the adult phase of the tree, the objective being to obtain an orchard that will last for centuries. In addition to its negative effect on production levels, the advanced age of the trees accentuates alternate bearing. Furthermore, the form of cultivation practised, which usually entails manual harvesting from the tree or from the ground, with vigorous cultivars which are often over-mature and tend to have small-sized fruit, rules out the possibility of using machinery for harvesting. Moreover, it is not easy to equip a traditional olive orchard with an irrigation system, and even when water resources are available they are not always used correctly. Furthermore, irrigation has a limited effect on olive orchards when the trees are old.

Salvaging these orchards by maintaining them, even when they are located in suitable areas, is not viable in economic terms. The only possibility is for them to undergo total transformation through re-planting. The restructuring or maintenance of such traditional olive orchards is justified only in olive-growing areas with ample manual labour at low cost or in family-type operations.

This can be done by adapting the traditional olive orchard using agricultural methods practised in the past, such as increased density, re-grafting or renovation pruning in order to intensify the crop and increase the yield to meet the potential offered by the environment. The salvage operations are most successful when irrigation is also introduced.

The factors which most limit the potential recovery of a traditional orchard are usually age (over 30 to 40 years), irregular layout, the lack of uniform development of the orchard and incorrect systematisation of the soil.

INTENSIVE CULTIVATION

The problem of how to increase productivity and keep down costs in the olive-growing countries of Europe arose at the end of the fifties, with the drop in availability of farm labour and the ensuing rise in costs. The problem was particularly intense in Italy as a result of the exodus of the rural population at that time. Morettini launched the idea of modern olive-growing based on specialised cultivation by proposing a substantial improvement in the techniques used for tillage, fertilisation, pruning and pest control. The most significant aspect of the proposal, however, was the introduction of a new form of training (known as the bushy vase, or *vaso cespugliato*) to replace traditional methods and a substantial increase in the number of plants per hectare (from 200 to 400). The purpose of this intensified cultivation was to improve production levels, while bushy vase cultivation was introduced to reduce foliage levels drastically by keeping the height of the trunk down to a minimum, thus facilitating manual harvesting and pruning operations.

The proposals of Breviglieri, which were made at practically the same time as those of Morettini, not only shared the latter's concern for the improvement of cultivation techniques, but were based on cultivation methods borrowed from fruit growing, such as the fan and Y-shape, which also involved low branching.

Furthermore, as these two shapes were fairly flat, the structure proposed for the olive orchard was a virtually continuous wall, with the trees relatively close together (4 m) and fairly narrow lanes between the rows (5 m). The objective was to control the development of the tree by using very careful pruning techniques to anticipate curving and to do away with surplus branches. To keep costs down, vehicles were to be used for both pruning and harvesting.

Whereas the bushy vase was applied to simplify training, with positive results in shortening the juvenile phase of the plant, the same cannot be said for the fan and Y shapes, because of the difficulties in making the species adapt to such excessively contrived forms. It can be said that the attempt to modernise olive cultivation along the lines proposed above and by other researchers at that time, in Italy at least, produced no concrete results for modernising olive cultivation in the widest sense of the term, although the intensive cultivation system is now well-established in the olive-growing world and is used to a varied degree in the different olive-growing countries. It should be added that, although some of the proposals for modernising olive-growing in the sixties have remained fundamental for the intensive cultivation system, the growth pruning methods proposed then to facilitate manual harvesting, pruning and pest control, irrespective of their degree of complexity, have been superseded by the objective of full mechanisation of olive cultivation while obtaining maximum returns.

As a result, the concept of intensive mechanised olive growing has undergone substantial changes in the last thirty years. By way of a definition, intensive olive growing should be envisaged as a cultivation system situated in a suitable area which, by using modern planting and cultivation techniques, is capable of achieving both maximum levels of production (in qualitative and quantitative terms) compatible with local environmental conditions, and of keeping production costs down through total mechanisation of all operations, in order to obtain a reasonable level of profitability.

It is now universally accepted that only by using intensive mechanised systems can the negative aspects of traditional olive-growing be overcome, in particular, modest and inconsistent productivity and high cultivation costs.

The introduction of this new system generally requires complete reconversion of the orchard because these objectives cannot be attained merely by restructuring traditional olive orchards. In addition, the new olive orchard should guarantee production in the short term. Modern technology helps olive orchards to give early yields (3rd or 4th year), reaching full production capacity between the 7th and the 8th year in irrigated orchards and between the 11th and 12th year in dry orchards, with production levels of not below 40-50 q/hectare in dry orchards and 70-80 q/hectare in irrigated orchards. These are then expected to remain constant for at least 40 to 50 years. An essential prerequisite for a successful olive orchard is the choice of environment for the orchard, which must be located in a suitable area.

Equally important is the choice of cultivar. An error in this respect would require re-grafting and would have negative repercussions on both the costs and the period within which the olive orchard could enter production. The general criteria for selecting cultivars are outlined below and illustrate that there is a substantial difference between orchards for table olives and for olive oil. In the former case, the choice is usually limited to a few cultivars, often only to one, depending on the processing industry and the market. However, in the second case, the choice may involve more cultivars, either to improve the harvesting period by selecting varieties with different maturation periods, or to ensure a more harmonious composition of the oil from the organoleptic point of view, notwithstanding the need to protect pollination in the case of incompatible cultivars. Furthermore, irrespective of the productive capacity and constancy of the selected cultivars, seasonal variations make it difficult for a given cultivar to show the same productive response year after year.

Other basic principles to be considered when choosing cultivars are their adaptability to the environment, their capacity in terms of early production, fruit-bearing constancy, the quantity and quality of the product, the length of the juvenile phase, suitability for mechanical harvesting, resistance to biotic (pests) and abiotic adversities (climatic and soil-related).

Another important element in selecting intensive cultivation systems is the plant type. In general, preference should be given to rooting plants over those obtained from grafting on generic seedlings – except in cases where it is possible to use stocks with particular characteristics in terms of vigour, productivity and resistance to soil factors and pests – because of the greater uniformity and shortened juvenile phase characteristic of plants which have taken root. It is also vital to choose potted plants grown in nurseries as this gives a reasonable guarantee that the roots will take, thus avoiding transplantation crises and it allows plantation to be performed over a longer time span.

With regard to orchard density (number of plants/surface unit), the current trend is to increase the number of plants per hectare. The layout must therefore be smaller than its traditional counterpart. Broadly speaking, this ranges from 5 x 6 m and 7 x 7 m in southern and northern environments respectively. Nevertheless, when making a selection, several criteria should be applied such as the vigour of the cultivar, the pre-selected training method, the fertility of the soil and the life of the olive orchard, bearing in mind that once a stable production rate is achieved, coverage of the orchard should not exceed 70-75%. The variation of layout and in particular of distancing along the row depends largely on the method of training: those with a greater ratio between the height of the tree and the diameter of the crown (single trunk, spindle-shaped, monoconical) may be placed closer together than those with a smaller ratio (vase, globe, bush, bushy vase), in both square and rectangular layouts (3-4 m apart).

It is also important to bear in mind that the distance between rows in square layouts and of the width of the lanes in rectangular layouts must allow the free movement of machines throughout the life span of the olive orchard. The possibility of reducing the layout to obtain the smallest distance between trees not only allows the number of plants per hectare to be increased but results in greater overall surface area of the crowns and thus makes it possible to obtain significant production levels from the 4th to 5th year after planting, and even greater levels in subsequent years, provided that the growth of the crowns is carefully controlled to guarantee maximum exposure to light and to avoid competition between adjacent plants. The use of vertical development growing (single trunk, spindle shapes, free single stalk) and proper pruning, irrigation and rational fertilisation can also help.

In addition to other aspects involved in the definition of the layout, the most suitable shape for intensive orchards must take other considerations into account, such as the simplification of pruning, in both the training and production phase, and the possibility of mechanical harvesting, without causing any negative effects on the rate of growth of the plant, the length of the juvenile phase, or its productivity.

With regards to table olive cultivars (especially for the production of green olives, where mechanical harvesting is still uncommon), the choice of tree shape and pruning technique is based on different criteria to those used for orchards producing olive oil. In this case, contained vertical development methods such as low vase, bush, bushy vase and low, monoconical are more suitable, and pruning should be geared to promoting the development of well-distributed fruit-bearing branches, located mainly on the external part of the crown giving good-sized fruit and facilitating manual harvesting.

Cultural care operations such as fertilisation, irrigation, pest control, soil management and harvesting processes should be carried out on a minimum budget with a view to optimising the productivity of the orchard in terms of constancy, quality and quantity.

These criteria are the basis of the agronomic model for intensive mechanised orchards using one-year-old shoots from productive, high-market-value cultivars, with layouts of 6 x 4 m and 6 x 3 m, and growing methods to attain predominantly vertical development such as moniconical and spindle-shaped that are suitable for mechanical pruning and harvesting. This model, which is widely applied in the olive-growing regions of Italy, has proved successful in meeting intensive cultivation criteria both as regards production levels (greater than 50 q/hectare) and keeping down manual labour costs (under 120 hours/hectare a year).

In order for olive-growing to become a profit-making enterprise, the social situation as well as the local, national and international market must be

Olive harvest. (Photograph by Gianluca Boetti).

evaluated. Whereas today's new intensive cultivation models make it possible to obtain qualitatively and quantitatively superior products at lower production costs than in the past, it is also true that profit, the ultimate objective of an olive-growing concern, depends on how much the olive grower is paid for his product. At present, far more than in the past, the price of olive oil is directly linked to the world market situation although there is still a distinction between the different categories. The top-quality product (extra virgin) which continues to make headway amongst consumers worldwide, can certainly fetch high prices both in relation to products of lesser quality in the same market category and to other, less select types (virgin and lampante oil). It is true, however, that it is still something of a basic food product and, as such, cannot easily be sold at very high prices, except for certain specific market niches. Consequently, in addition to increasing productivity and keeping down cultivation costs, the objective must be to organise the market. Producers should have a greater part to play within the market so that supplies can be better concentrated in order to balance out the power of the industry and prolong the production cycle right down to consumer level, at least for the top-quality products.

The development of olive cultivation through the expansion of intensive cultivation systems in traditional olive-growing and new areas must also take market developments into consideration in order to avoid surplus production and competition at world level, so that farming concerns do not die out either in countries with a more developed economy where production costs are relatively high, or in other countries which ostensibly benefit from the lower cost of manual labour, but in which the weak position of the producer may favour speculation by foreign industry.

POSSIBLE DEVELOPMENTS IN CULTIVATION TECHNIQUES

The successes obtained from mechanisation in many agricultural sectors are due to a perfect integration of mechanical and agronomic innovations. This evolutionary process occurs only partially in olive growing, in the sense that although new intensive models save time and cut costs, compared to traditional methods, they do have limitations for the future.

Production efficiency and full mechanisation of cultivation operations in olive farming are still more of a goal to be aimed at than an achieved objective.

Bearing in mind market trends, the need for careful management of natural resources and the opportunity to attain maximum production efficiency with minimum expenditure of economic, natural and human resources, the current models of intensive, mechanised orchards seem far from perfect. Substantial improvements could be obtained by selecting more productive cultivars giving a higher oil yield that are resistant to biotic and abiotic factors and are fully compatible with the mechanisation of pruning and harvesting, just as the varieties used today were selected in the past for different cultivation purposes. It is a well-known fact that traditional methods of cultivation relied on vigorous cultivars suitable for dry cultivation and for orchards which lasted for centuries. Furthermore, from the point of view of mechanisation, although there are highly-efficient trunk vibrators on the market today, this machinery may be further improved in future to optimise mechanical harvesting.

This is the underlying premise of the recently proposed agronomic model of an intensive, mechanised orchard which recommends the use of vertical-standing varieties suitable both for mechanical harvesting with trunk vibrators and for close-row layouts. The plants are allowed to grow more or less freely up to a uniform height so that the fruit-bearing surface area develops vertically.

The development of intensive orchard models based on discontinuous systems of mechanical harvesting may lead to improved plant productivity and economy of cultivation, but only within certain limits. New paths are being explored which go far beyond the limits imposed by this system and develop a very different orchard model. A case in point is the research into a new agronomic model, still in its experimental phase. This consists of high intensity systems (about 1000 plants per hectare) designed for continuous mechanical olive harvesting, using a machine for a combined system of combing and vibrating on the external side of the canopy to loosen the fruits which are collected on conveyor belts and transported to containers. The same machine will be able to carry out other operations (pruning, pest control, weeding) by changing accessories. However, the actual development of this model will depend on the availability of compact cultivars or dwarf stocks which would guarantee high productive efficiency because of the greater overall surface area of the canopy while enabling the machine to be used. The integral mechanisation system, whereby all operations are mechanised, ensures that the machine is put to continuous use, eliminating idle times and drastically reducing the use of manual labour, which will not exceed 50 hours per hectare a year.

The development of such highly intensive orchard models will become a reality in industrialised countries, where the percentage of the population working on the land is already low and can be expected to drop further in future so that only completely mechanised systems are viable. Highly-advanced technologies are required to reduce cultivation costs as far as possible.

GENETIC IMPROVEMENT

The olive as a species has not yet been much affected by genetic improvement programmes. Research in this field has focused essentially on the selection of varieties and clones, and on induced metagenesis, but has had no notable results except for varietal selection.

Whereas from the agronomic point of view, varietal or clonal selection helps improve the standard of a particular cultivar, from the genetic point of view it tends to reduce the existing variability. It is of fundamental importance, therefore, to ensure the conservation of germ plasm to avoid the risk of genetic erosion.

Genetic improvement of the olive by cross-breeding has been undertaken in a systematic manner since 1980 in China to create cultivars which are more suitable to the local soil and climatic conditions.

Recent work on genetic improvement by mass selection has yielded the two Israeli cultivars – Kadesh for table olives with an extremely low oil content, and Barnea for oil with high productivity – as well as the Italian cultivar FS-17, characterised by self-fertility, high productivity and very early oil formation. Furthermore, two clonal stocks, the FS-17 and the DA-12, have been patented in Italy, the first of which is a dwarfing stock.

Biotechnology applied to the olive for in-vitro production of new cultivars is still in the preliminary study phase and geared to the production of individual homozygotes using haploid tissues or somatic hybrids through the fusion of protoplasts, somaclonal variations and DNA manipulation. Our knowledge of variety characterisation from techniques based on isoenzymatic discrimination through electrophoretic or Restriction Fragment Length Polymorphism (RFLP) is rather limited.

Although the olive has a rich genetic heritage, cultivars meeting the new cultivation requirements are still not available whence the need for genetic

(Photograph by Gianluca Boetti).

improvement programmes. These programmes should focus on three basic objectives:

- to increase production potential;
- to create cultivars that are better suited to intensive cultivation systems; and
- to improve the quality of the product (olives and oil).

In order to attain the first objective, the genetic traits determining productivity must be identified: adaptation to pedological and climatic conditions of typical areas of cultivation, and greater distribution of assimilates towards the reproductive organs (fruit-bearing branches) than towards the vegetative organs (wood branches), taking due care, within limits, not to hinder the growth of the plant.

The second objective is linked to the technological development of olive growing in the years to come and to the sectorial policies implemented and pursued in the different countries. Work on genetic improvement is currently geared primarily towards intensive cultivation with high technological input, and is thus restricted to suitable areas. In some situations, however, such aims may also be pursued by taking into consideration aspects such as resistance to negative climatic and pedological factors. As far as mechanisation is concerned, trunk vibrators and pruners are being used more and more. It will therefore be necessary to have cultivars giving medium-sized fruit with less attachment strength, not very progressive maturation and upright stance to ensure the rigid structure of the canopy. Technological development towards dense orchards, based on the use of straddling machines for harvesting, is gearing genetic improvement towards the selection of 'compact' genotypes to reduce layouts and increase the photosynthesis area.

The third objective depends on the intended use of the product. Whereas the genetic traits which contribute to the quality of table olives are relatively well-known, although aspects relating to the organoleptic characteristics of the processed product are yet to be defined, the matter of olive oil quali-

ty is more complex. By and large, the aim is to achieve a quality rich in aromas and with constituents capable of increasing preservability.
The following list classifies the objectives for genetic improvement of the olive, in terms of both cultivars and stocks.

Objectives of general interest

Increased productivity involving:
- shortening the juvenile phase;
- quantity (olive and/or oil);
- fruit-bearing constancy;
- self-fertility, a factor probably related to productivity.

Adaptation to intensive cultivation systems by identifying:
- genotypes suitable for full mechanisation of cultivation operations;
- compact genotypes for dense orchards.

Rhizogenic capacity.
Resistance to the main pathogens.

Objectives linked to the intended use of the product

For oil cultivars:
- early oil formation;
- increased oil yield;
- simultaneous ripening;
- improved oil characteristics (organoleptic quality, preservability, absence of defects).

For table-olive cultivars:
- improvement of fruit characteristics (size, flesh-to-stone ratio, organoleptic characteristics, response to treatments).

Specific objectives for olive-growing areas characterised by restrictive environmental factors

Resistance to stress
- cold;
- drought;
- salinity.

Adaptation to abnormal soils;
- clayey;
- superficial.

Objectives for stock selection

- high rhizogenic capacity;
- control of the vigour and behaviour of the graft combination;
- resistance to drought, salinity and clayey soils;
- resistance to diseases of the root apparatus or the vascular system.

When examining certain traits which can be improved genetically, indications and, where possible, information as to their probable transmission should be given.
The «early fruit-bearing» trait of the shoot has a positive connection with the shortness of the juvenile phase of the parent trees. In olives, it has been observed that Picholine seedlings, which are early cultivars, have a shorter juvenile phase than others. Such a trait is present in other culti-

vars such as Leccino, Ascolana Tenera, Pendolino, Coratina, and in the new selection I-77.

As regards «fruit-bearing constancy», it has been observed that the alternate bearing pattern (biennial, pluriannual) is a characteristic of the cultivar. This trait should be studied in greater depth, however, to ascertain whether genetic factors are involved or whether it is due to cultivation techniques.

For the «ovary abortion» trait, some observations indicate that cultivars with more than 60% of ovary abortions are as productive as other cultivars with an ovary abortion rate of under 10%, or even more so.

As regards the «oil content of the fruit», a trait which varies depending on the cultivar, a significant correlation has been observed between the quality index of the fruit (given as the oil content in relation to the weight of the fruit) and the leafing index (LAI); moreover, the quality index of the fruit is predominantly inherited from the mother plant.

Other traits such as «stone length» and «fruit length» show high heritability, whilst the low ratio observed in the olive between the pulp weight and the weight of the stone suggests that this ratio could be improved genetically.

«Vigour» is known to differ from one cultivar to another, despite the fact that, in most cases, the most widespread varieties fall into a medium-high category. The «compact» trait in the olive has not been studied in sufficient depth to date. The only information available is from genetic improvement research carried out in China, which has succeeded in obtaining reduced-size cultivars. Clones with low vigour have also been selected from existing cultivars, for example the Amigdaloila Nana in Greece and I-77 in Italy. Briscola, a cultivar obtained in Italy through induced metagenesis with gamma rays, is of no agronomic interest.

Olives vary greatly in «rhizogenic capacity». Apart from cultivars which do not take root at all, others register rooting percentages close to 100%. The mechanisms which enable these traits to be transmitted have not yet been identified.

In terms of «resistance to pests», in the absence of research, it can only be said that different varieties behave differently. In the case of *Spilocaea oleaginea*, for example, the less sensitive cultivars are considered to be Ascolana Tenera, Cellina di Nardò, Dolce Agogia, Farga, Leccino, Leccio del Corno, Lechin, Koronaiki, Nevadillo Blanco, Nocellara Etnea, Mignolo, Ottobratica, Piangente, Sevillano, Zaituna and Zorzaleno. Information regarding varietal resistance to tracheoverticilli (*Verticillium daliae*) is available for cultivars like Oblonga, while it has been pointed out that the seedlings of the Chemlali, Frantoio, and Arbequina cultivars are more resistant to pests than seedlings of other cultivars. As regards the olive fruit fly (*Dacus oleae*) and the olive moth (*Prays oleae*), apart from evidence that the cultivars are more sensitive to early maturation, it is not known whether the «pest resistance» trait is found in *Olea europaea* or other related species.

In respect of abiotic factors and «resistance to cold» in particular, considerable information is available on the susceptibility and resistance of numerous cultivars in cold olive-growing regions. Work carried out in China with many different varieties has shown that shoots of cultivars from cold countries were significantly more resistant than shoots from Albanian cultivars.

As regards «resistance to drought» and «resistance to salinity,» generally speaking the most resistant cultivars are those selected in North African

Example of olive cultivation in rows (Photograph by Gianluca Boetti).

and Middle Eastern countries, which have a drier climate. However, there are no systematic observations available and the mechanisms by which such traits are inherited are as yet unknown.

Despite the wide genetic variability of *Olea europaea* already mentioned, there is no information available on which characteristics are determined according to epigenetic, monogenic or polygenic factors, and in the latter case, on whether it is a matter of additive or interactive heredity. The lack of information on genotype characteristics means that only parents evaluated on a phenotype basis can be used for work on genetic improvement. As regards selection criteria, no specific studies are available on the correlation between genotype and phenotype. Consequently, the only alternative is to select, from among the seedlings obtained, individuals which are superior to their parents in the traits to be improved.

The following methods are used for the genetic improvement of the olive:

- Mass selection. This method consists of selecting, on the basis of phenotypical characteristics, the best individuals of a population. When allowed to pollinate freely, they will produce an F1, where the best individuals will subsequently be selected to constitute the new seed-bearing line for the next selection, or to constitute new cultivars directly. Selection using this method is based exclusively on maternal characteristics.
- Recurrent selection. This method entails crossing two parent plants selected on the basis of phenotypical characteristics, and the genotypes with favourable traits are re-crossed in every generation in all possible combinations. As in the case of F1, new cultivars can also be constituted.
- Re-crossing. This method is used to transfer a specific trait to an agronomically validated cultivar. The latter is used as the recurrent parent and is crossed with another which has that specific trait. The individuals which have the desired trait are selected in every generation and are re-crossed with the recurrent parent. This process ultimately leads to a new cultivar, where a new trait is added to those of the variety in question.
- Hybrid varieties. These varieties are obtained by crossing two pure lines. Because pure lines in the olive can only be obtained after a long and complex process, this objective is unlikely to be reached unless homozygotes from haploid tissue cultures are available.

Pollination technique

Because of the difficulty of emasculating olive flowers, cultivars rendered self-sterile by crossing should be used for genetic improvement (except where pure lines are sought). The degree of self-sterility, although genetically controlled, may vary depending on the environment or be modified in micro-environments, as happens when the flower-bearing shoot is placed inside a terylene bag for controlled crossing. It is therefore necessary to choose self-sterile, seed-bearing plants and to check that they are also effectively self-sterile when inside the bags.

The flower-bearing shoots selected for crossing are put in bags at least one week before flowering and their number should be double that of the pollination shoots. The total number of bagged shoots depends on the number of flowers, the breeding percentage and the germinating capacity of the seeds. The population of the seedlings obtained by crossing must not be less than 100 individuals so that they are sufficient to study variability. When half the flowers are open, pollination can occur by placing the pollinator shoots inside the bags containing the seed-bearing plants. Once closed, the bags are shaken.

The olives obtained from crossing will be harvested in the intermediate phase of maturation, when their seed has attained maximum dry weight. In that phase the seeds germinate sooner and do not require stratification, presumably because germination inhibitors have not accumulated. Once the pulp has been eliminated, with or without rupture of the endocarp, the seeds are sown in a controlled environment.

The problem of the juvenile phase

Olive seedlings have a very long juvenile phase and, under natural growth conditions, begin to bear fruit only 15 - 20 years after germination. This is one of the main obstacles for selection programmes involving crossing. There are two ways to solve this problem: by establishing correlations between the morphological traits of the seedlings and the agronomic behaviour in the adult phase, thereby allowing for early selection without waiting for the plant to develop, or by reducing the juvenile phase by means of appropriate seedling breeding techniques. The first alternative is not practised at present because of the lack of specific information on the subject. It is, however, possible to try to reduce the juvenile phase. On the basis of current knowledge and in order to contain the juvenile phase of olive seedlings, action should be taken in the initial growing phase to accelerate the height of the plants. This is because, in order to obtain flower differentiation, the plants must attain sufficient height, as is amply demonstrated in other species. Thus:

– the plants should be grown in the erect position;
– they should be maintained in a continuous growing phase;
– pruning should be avoided as far as possible, with the exception of the lowest branches;
– fertile substrates should be used with abundant fertilisation.

When the seedlings have reached the transition phase (i.e. from the juvenile to the adult phase), which is characterised by the disappearance of the wild traits and the appearance of traits corresponding to the mature phase, the plants become potentially fertile. During this phase, certain actions can prove useful in accelerating the first yield, such as:

– grafting on adult or dwarfing plants;

- elimination of lateral branches;
- treatment with florigenous phytoregulators;
- imposing stress conditions which hinder growth such as cold, lack of water and root pruning.

Direct experience already exists for some of these techniques. For example, positive results have been obtained by growing seedlings in a greenhouse and maintaining the plants in an erect position until flowering, which occurs 5-6 years after germination. In this way, the plants can produce a few fruits after a reasonable period – sufficient to allow an initial evaluation of their morphological characteristics. For a definitive evaluation of their productivity, greater canopy development is required, which can be achieved by transferring the plants to bigger containers or directly to the fields. This method has been used in Israel where, in warm environments with abundant water and nutrients, combined with continuous pruning to eliminate the lowest branches, with seedlings grown in the ground, the first flowering has been obtained in the 3rd or 4th year after transplantation.

VARIETAL CLASSIFICATION

The olive belongs to the *Oleaceae* family, which comprises nearly 300 genera and 600 species. The cultivated olive belongs to the genus *Olea*, species *europaea*, subspecies *sativa*, which is distinguished from the other subspecies, *oleaster*, to which the wild olives spread around the Mediterranean belong. These are said to derive from *Olea europaea* as a result of spontaneous dissemination and segregation of traits. Recent studies tend to re-arrange the classification of the genus *Olea* by identifying forms, cycles and heterotypical synonyms of the different species found in Africa, Asia and Australasia.

There are 23 (2n=46) chromosomes in all the species of the genus *Olea*. Existing varieties belonging to *Olea europaea* are extremely numerous. It can be said that few cultivated species boast such a wealth of varieties as the olive, which is estimated to have more than 2,000 cultivars. Varieties known to have existed in remote times are undoubtedly still being cultivated today in olive-growing countries, although the development of language has changed the original name thus hindering identification in the descriptions written by ancient authors. There is also a possibility that, as cultivation systems evolved, some varieties disappeared to give way to improved, more productive genetic entities, with bigger fruit, greater oil content, greater resistance to pests, etc., and that new varieties originated spontaneously by natural dissemination.

Moreover, in certain especially difficult climatic situations, the species might have established itself owing to the existence of specific cultivars bred from imported germ plasm as well as from new genetic entities. Despite the fact that many cultivars were described in ancient times, there are many still unclassified and others that are totally unknown. In areas where olives have been long established and where technical development has been scarce, it is not hard to find ecotypes of ancient origin, which are identified or known only at local level. The identification and classification of varieties of olives is further complicated by the presence of numerous homonyms and synonyms, as yet uncodified, whereby different varieties are labelled with the same name (homonyms) or are given different names (synonyms) in the same or a different environment. The main difficulty in distinguishing the various cultivars is that there are still no genetic evaluation methods in the strict sense of the term, with the exception of a few attempts at iso-enzymatic studies using electrophoretic methods that have been carried out in Greece, Spain and France on shoots, leaves and tips of roots since 1970. The greatest problems arising in the application of these techniques are the qualitative and quantitative changes of the iso-enzymes, which make new bands appear and others disappear during the various development and growth phases of the plant, as a result of which sampling becomes difficult. For a proper interpretation of the electrophoretic data, both the quantitative and qualitative differences should be considered, even though the former indicate the basic variations in the structure of the proteins and have a direct effect on the distinction of the genes. The genetic distance between the cultivars can be determined by means of the similarity index (SI) which is the ratio (in percentage) between the number of homologous bands and the number of total bands.

The enzymatic systems studied to date represent only a small fraction of the loci of the entire genome of the olive. This is also because the techniques are only known for a few of them. For this reason, even when no iso-enzymatic differences are encountered, genetic variation cannot be entirely excluded. In addition to isoenzymes, other biochemical markers can be used for the identification of varieties (for example, carotenoid pigments subjected to thin-layer chromatographic analysis). However, as the enzyme

Olives growing in the area betwen Basilicata and Puglia. (Photograph by Gianluca Boetti).

systems are produced directly from the genes, they indicate the genetic differences between cultivars with the greatest precision. Only RFLP analysis provides a complete knowledge of the entire genome of the olive but work in this direction is still in its initial phases.

Because of the difficulties of applying the analytical techniques used to differentiate varieties on genetic bases, the various cultivars have so far been evaluated in relation to morphological, biological and agronomic traits. The principal classification methods are reviewed briefly below.

Classification based on morphological traits

In the early years of the nineteenth century, Tavanit proposed the shape of the stone as a basis for classification and classified the various cultivars into 21 groups. The method has since been used by other authors.

Morpho-biological classification

The basic elements in this method are the morphological traits of the fruit and the leaf, in addition to other evaluation elements of the biological and agronomic behaviour of the plant, from which a complex and detailed index can be drawn up as proposed by authors such as Ciferri, Marinucci and Morettini.

The compilation of data has made it possible to divide the traits into two groups:

- Fundamental traits, including the morphological characteristics of the drupe and the pit, which make it possible to distinguish groups of cultivars which resemble each other;
- Secondary traits, which are subdivided into morphological characteristics relating to the leaves and to the bearing of small branches, and biological and agronomic characteristics. Secondary traits are used to identify cultivars within homogenous groups.

Nevertheless, several environmental factors or different systems of cultivation can cause phenotype changes (fruit size, leaf size and colour, length of the internode, flowering time, etc), and although certain traits such as the bearing of the tree, the shape of the fruit, the leaves and the pit are rather stable, it is not always possible to identify a cultivar with absolute certainty.

From the agronomic point of view, varieties are classified using a more practical method which subdivides varieties depending on the intended use of the fruit. On the basis of this criterion, olive cultivars are differentiated as oil cultivars, table-olive cultivars and dual-purpose cultivars.

Oil cultivars are cultivated primarily for the extraction of oil and are characterised by a variable oil content, normally not below 16-18%. The fruit is usually medium to medium-small in size, and weighs between 1 and 3.5 g. The stone-to-flesh ratio is relatively low.

In table olive cultivars the processed fruit is intended for direct consumption. It is large to medium-large in size and weighs 5 - 17 gr. It has a high stone-to-flesh ratio and the oil content is generally low. It is possible to distinguish the various table olive cultivars intended primarily for the production of green olives from those intended primarily for the production of black olives.

Dual-purpose cultivars are those which can be used either for the extraction of oil or for the production of table olives. The fruit characteristics fall between those of the two groups described above.

A list of the most important cultivars from the various olive-growing countries is given below according to the use given to the fruit.

ITALY

- Oil cultivars: Barese, Biancolilla, Bosana, Canino, Carpellese, Casaliva, Castiglionese, Cellina di Nardò, Cerasuola, Coratina, Corregiolo, Dritta, Frantoio, Gargnà, Gentile di Chieti, Gentile di Larino, Leccino, Maurino, Messinese, Moraiolo, Ogliarola di Lecce, Olivella, Ottobratica, Pendolino, Pisciottana, Procanica, Ravece, Raja, Razzola, Rotonda, Rotondello, Rosciola di Rotello, Santagatese, Sargano, Sinopolese, Taggiasca.
- Table olive cultivars: Ascolana Tenera, Bella di Cerignola, Bella di Spagna, Caizzana, Giarraffa, Nocellara del Belice, Nocellara Etnea, Pizz'e Carroga, Santa Caterina, Sant'Agostino, Tonda Iblea, Uovo di Piccione, Zaituna.
- Dual-purpose cultivars: Ascolana Semitenera, Carolea, Cucco, Grossa di Cassano, Intosso, Itrana, Maiatica di Ferrandina, Messinese, Moresca, Nera di Gonnos, Nocellara, Passalunara, Provenzale, Tonda di Cagliari.

SPAIN

- Oil cultivars: Alameno de Cabra, Aloreña, Arbequina, Avellanejo, Blanquillo, Carrasqueño de Alcaudete, Carrasquillo, Chorreao de Montefrío, Datilero, Lechín de Sevilla, Manzanilla de Huelva, Manzanilla Picúa, Morcal, Negrillo de Arjona, Negrillo de Estepa, Negrillo de Iznalloz, Negro, Nevadillo, Picual, Picual de Almería, Rechino, Torcio, Verdial de Vélez-Málaga, Zorzariega.
- Table olive cultivars: Buidiego, Campanil, Cañivano Blanco, Canivano Negro, Cornezuelo, De Sal, Dulzal, Gordal, Gordal de Archidona, Gordalejo, Imperial, Limoncillo, Loaime, Manzanilla, Manzanilla de Almería, Manzanilla de Agua, Manzanilla de Montefrío, Manzanilla de Piquito, Manzanilla de Jaén, Manzanilla-Cacereña Morona, Picudo, Tomadillo.
- Dual-purpose cultivars: Bical, Carrasqueño de la Sierra, Changlot Real, Galego, Gatuno, Hendeno, Hojiblanca, Lechín de Granada, Manzanilla Prieta, Manzanilla de Zahara, Mollar, Ocal, Pico Limón, Rapasayo, Royal, Verdial de Huevar.

PORTUGAL

- Oil cultivars: Alentejana, Cobrancosa, Madural, Mora, Verdeal Picual, Verdeal Transmontana.
- Table olive cultivars: Azeitoneira, Gordal, Hojiblanca, Negrinha.
- Dual-purpose cultivars: Algarvia, Bical de Castelo Branco, Blanqueta, Branquita, Conerva de Elvas, Cordovil de Castelo Branco, Cordovil de Serpa, Galega Grada de Serpa, Galega Vulgar, Macanilha, Macanilha Carrasquenha, Macanilha Carrasquenha de Almendralejo, Redondal, Redondil, Verdeal Alentejana.

FRANCE

- Oil cultivars: Araban, Argental, Blancal, Bouteillan, Cailletier, Moiral, Olivière, Pendoulier, Pigalle, Pignole, Rendonan, Ribier, Rouget, Sayern.
- Table olive cultivars: Lucques.

- Dual-purpose cultivars: Aglandau, Amellau, Argoudeil, Belgentièroise, Bouteillan, Cailletier, Germaine, Grossanne, Pagètoise, Picholine, Poumal, Pruneau de Cotignac, Solonenque, Tanche, Verdale.

GREECE
- Oil cultivars: Agouromanacolia, Corfolia, Koroneiki, Daphnoella, Daphonolia, Mastoidis Grande, Mastoidis Micra, Smertolia, Throumbolia, Vanalolia.
- Table olive cultivars: Adrocarpos, Amygdaloila, Konservolea, Halkidiki, Mastoides, Stravolia.
- Dual-purpose cultivars: Adramittini, Carydolia, Kalamata, Methonia, Megaritiki, Vassiliki.

YUGOSLAVIA
- Oil cultivars: Beleka, Belica, Lastovka, Zutika.
- Dual-purpose cultivars: Buga, Crnica, Istrica Belica, Oblica.

ALGERIA
- Oil cultivars: Abelout, Chemlal, Faneya, Haimel, Limli.
- Dual-purpose cultivars: Adzeradj, Blanquete de Guelma, Bouchouk de la Soummam, Bouchouk Lafayette, Sigoise.

TUNISIA
- Oil cultivars: Chemchali, Chemlali, Chetoui, Gerboui, Zalmati.
- Table olive cultivars: Gerboui, Meski, Saiali, Zarazi.
- Dual-purpose cultivars: Barouni del Sahel, Besbessi, Gerboua, Limi, Marsalina, Ouslati, Tefahi, Zarazi del Sud, Yacouti.

TURKEY
- Oil cultivars: Cakir, Cilli Gilek, Edremit, Memecik.
- Table olive cultivars: Aydin Memecik, Ayvalik, Celebi, Domat, Erkence, Gemlik, Izmir Sofralik, Memeli.

IRAQ
- Oil cultivars: Ajrosi, Barmaghi, Bashika, Dikkam, Kasb, Jelin.

USA (CALIFORNIA) AND MEXICO:
- Table olive cultivars: Ascolana Tenera, Sevillana.
- Dual-purpose cultivars: Manzanilla, Mission.

ARGENTINA
- Oil cultivars: Arbequina, Frantoio, Leccino.
- Table olive cultivar: Arauco.
- Dual-purpose cultivar: Empeltre.

CHILE
- Oil cultivar: Liguria
- Table olive cultivars: Azapa, Olivos.
- Dual-purpose cultivars: Empeltre, Manzanilla, Sevillana.

CYPRUS
- Oil cultivars: Coroneiki, Mastoides.

- Table olive cultivars: Conservolia, Cucco, Kalamata.
- Dual-purpose cultivar: Ladoelia.

ISRAEL

- Oil cultivar: Barnea.
- Table olive cultivars: Kadesh, Manzanilla, Mehravia, Uovo di Piccione.
- Dual-purpose cultivars: Muhasan, Nabali Baladi, Souri.

MOROCCO

- Table olive cultivar: Meslala.
- Dual-purpose cultivars: Haouzia, Manzanilla, Picholine Marocaine.

PAKISTAN

- Table olive cultivar: Gemlik, Uslu.

SYRIA

- Oil cultivar: Zaity.
- Table olive cultivars: Abou-Salt, Djlat, Kaiss.
- Dual-purpose cultivars: Dan, Doebli, Khodeiri, Koudeiry, Sorani.

PROPAGATION METHODS AND BREEDING TECHNIQUES

The propagation methods used for olives, as for other fruits, are reproduction and multiplication. In practice, however, reproduction is used for genetic improvement purposes or to obtain seedlings to be used as stocks. This is because the varietal characteristics of the mother plant are not reproduced in the seed plant, only in direct (cutting, ovule, sucker) or indirect (graft) propagation.

Multiplication is based on the possibility of creating new individuals either from portions of the plant (cutting, ovule, sucker) that are capable of regenerating the missing parts or by grafting.

Several of the direct propagation methods used in the olive are very ancient and probably date back to the very first endeavours to cultivate the species. Nevertheless some methods, such as propagation by ovule, sucker or hardwood cuttings, now considered traditional, have lost a lot of ground and have been substituted by modern methods such as grafting on seedlings and leafy stem cuttings. Furthermore in some olive-growing Mediterranean countries, traditional systems are still widely used both because of their simplicity and because of the characteristics of the plants.

Despite its ancient origins, grafting has undergone considerable development and is now a modern technique as a result of the perfection of grafting on young seedlings, which brought about the start and spread of industrial nurseries at the end of the nineteenth century. It is still a widely-used technique but is now used far less in large-scale breeding, because of its manual complexity, the non-uniform growth of the resulting plants and late entry into production. These drawbacks are partially reduced by the use of clone stocks, selected for specific traits. The various methods of direct propagation are described below.

Propagation by ovule

This method is based on the use of ovules, special hyperplastic formations which grow spontaneously, usually around the collar area and the bottom

(Photograph by Gianluca Boetti).

part of the trunk of adult plants. The ovules are rich in latent buds and contain reserve substances which, when separated from the tree, can feed numerous buds and roots which develop during the subsequent vegetative season. They are removed during the autumn-winter period and planted at a depth of 20-25 cm in the ground. This method mutilates the mother plant and does not yield large numbers of new plants.
This ovule propagation method led to the propagation system developed in Greece in the seventies, based on the use of fragments of ovular mass which are treated in nurseries using a technique similar to that used for the hardwood cuttings. In this case, the mother plant is irreparably damaged.

Propagation by suckers

This method uses suckers which grow naturally at the collar of adult plants directly from the ovules. Numerous roots form at the base of the soil-covered shoots and once an autonomous root apparatus has developed, it is separated from the mother plant and transplanted. To promote root growth at the base of the suckers, in addition to covering it with soil, annulation can be practised or notchings at the point where the sucker is inserted, or rhizogenic hormones can be used. Although simpler than the preceding method, it is not used for large-scale breeding because of the manual labour required and the limited number of plants which can be obtained from a single mother plant. Furthermore, plants from suckers, like those from ovules, have a long juvenile phase and start production fairly late.

Propagation by cuttings

This method is based on the use of a portion (cutting) of an adult branch (3-4 years) which forms new roots and new shoots autonomously from latent buds. The method was widely applied in the past and is still in use in some countries such as Spain and Portugal, with cuttings being planted directly in the field. It has been improved recently by using large bags filled with light soil in which the branch cuttings are placed to take root after treatment with root-inducing hormones.

The drawback of this system in practical terms is the large quantity of material required per mother plant which is normally taken from pruned wood.

Propagation by leafy stem cuttings

This method was developed in the United States by Hartman during the fifties, and was disseminated throughout the world under the name of «Mist propagation». It is the most widely used method in industrial olive breeding. Because it uses relatively small-sized portions of branches which are one year old or less, it has enormous advantages over former methods since each mother plant provides large quantities of propagation material. The method is based on the capacity of a leafy stem to produce roots after it is separated from the mother plant, treated with hormones and placed in specific environmental conditions. The cuttings are placed in a bed containing a suitable rooting product, inside a greenhouse under intermittent mist. Conservation of the functional activities of the leaves during the entire rooting process is essential to ensure the formation and initial development of the roots. The response of the cuttings to rooting in terms of root emission speed and quantity is highly influenced by synthetic hormone treatment (indolbutyrric beta acid or IBA), the temperature of the rooting mix (around 20-22°C), the cultivar (genetic factor), the period when the branches were picked (seasonality) and the nutritional condition of the mother plants.

Mist propagation has its drawbacks, however, the main one being the complexity of the structures required (automatic mist control system). In addition, prolonged spraying of cuttings for the entire rooting period (50-60 days) can lead to necrosis of the axil buds resulting from the deposit of salts contained in the water and impoverishment of reserve substances.

An alternative to mist propagation is the closed frame technique developed in the early seventies. This method involves the planting of the cuttings inside a closed frame, inside which it is possible to control the main factors favouring root formation. The propagation material is essentially the same as that used in mist propagation but is much simpler, in particular as regards the structures used and management.

The frame consists of a bed, the lower part of which contains a rooting medium (normally perlite), which provides support to the cuttings and holds moisture. It is maintained at optimum temperature levels by means of a thermostatically-controlled heating circuit. The upper part of the frame is enclosed with polyethylene that is transparent to light and permeable to gas and maintains high humidity. The frame must be placed in a rooting greenhouse of appropriate dimensions which must be well shaded by whitewashing the greenhouse and covering 75% of it with a shading net, or in a climatised greenhouse. Inside the frame, excess humidity of the rooting mix must be avoided through adequate drainage, and the relative humidity must be kept at 100%. The rooting mix should be maintained at an average temperature (20-22°C) for the entire duration of the cycle.

Propagation from cuttings comprises three phases: rooting, hardening and maturing.

The first starts with the collection of branches from the mother plant and the preparation of the cuttings. This aspect is fundamental if the operation is to be successful and must take into account all the factors which influence rooting capacity, both those intrinsic to the cutting (branch type and portion, cultivar, characteristics of the mother plant, seasonality) and extrinsic (internal and external conditions of the frame, treatment of the root-forming phytoregulators, cutting preparation technique). One-year-old branches, capable of bearing fruit, are picked in the spring from the outside of the canopy; they must be well-hardened, with an average diameter of not less than 2.5-3 mm.

The cuttings consist of branch portions with 4-6 nodes, on which only the four leaves of the two final nodes are left. The base cut is made immediately below the node to assist in healing. The cuttings are then treated with rhizogenic phytoregulators (indolbutyrric acid or IBA, naphtalenacetic acid or NAA, or a mixture of the two, in a hydroalcohol solution or dispersed in talcum powder), and planted in the mix at a depth not exceeding 3-3.5 cm.

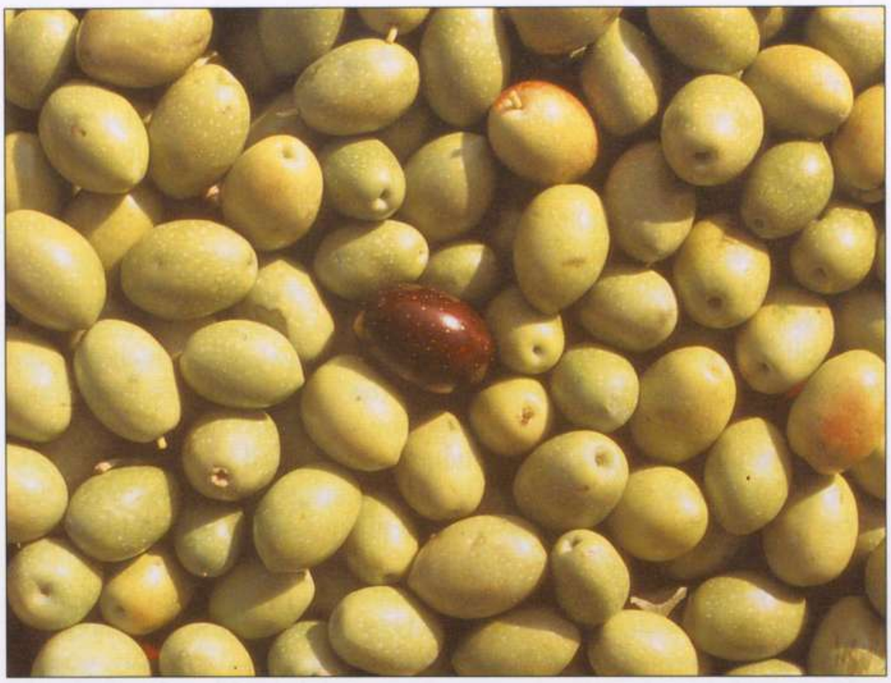
As already mentioned, rhizogenic potential is subject to genetic influence and there are considerable differences between one cultivar and another. This trait has been found in most, if not all, cultivars. Generally, even in cultivars with a good rooting capacity, the material should preferably be obtained from young, well-nourished plants, preferably irrigated, with a good vegeto-productive equilibrium. They should also be checked from the plant health viewpoint.

The rooting capacity of the cuttings is directly influenced by the vegetative state of the plant when the branches are picked, as the nutritional conditions and hormonal balance of the branch and of the cutting depend on this. In general, the period of peak rooting capacity occurs during vegetative activity in the period from March to November-December, with the exception of the hottest months.

The second, hardening phase, begins with the uprooting of cuttings which have produced a good root apparatus (at least three roots, 3-4 cm long) and ends with the stabilisation of the plantlets. Cuttings which have taken root are transplanted to small containers and kept in a greenhouse for careful control of light intensity (to which young plants are particularly sensitive) and temperature, which should not fall below 12-15°C initially. During this phase the young plants start to adapt to autonomous life by extending their own root apparatus, and the vegetative activity of the axil buds produces new shoots. The only operation required during the hardening phase – in addition to keeping the environmental conditions under control – is regular watering.

The third, growing phase, consists of hardening the plantlets in the nursery until they are ready to be transferred to the field. Whereas in the past this phase was carried out in planting beds, it is now done in pots.

This technique consists of growing the young plants in appropriate containers with suitable soil and sufficient fertilisation to guarantee optimal growth of the plant in terms of the overall development and quality of the root system, essential for rooting and rapid growth in the field. With this technique, the plants are grown in plastic 2-3 litre pots, using a compost consisting preferably of sandy silt loam, peat, litter, or other organic material, and coarse river sand in a volumetric ratio of 2:1:1:1. The prepared compost is mixed with mineral fertiliser containing nitrogen, phosphorus,



(Photograph by Gianluca Boetti).

potassium and micro-elements. The hardened plants are transplanted in the spring. The pots are placed on the ground under a tunnel, 70% protected by shading nets on a black plastic sheet and are provided with a drip irrigation system to ensure regular water and maintain the substrate in optimum humidity conditions. The system also allows hydrogenated fertirrigation throughout the growing phase. A mist system can also be used which, although structurally less complex than the preceding one, requires greater availability of water. To obtain single-stem plants, one shoot is selected early and held erect by a tutor. At the end of the vegetative season, the plants will have grown to an adequate height suitable for planting.

In more advanced olive breeding, the technique of growing young plants in containers is now the most popular method, with variations depending on the type of container, the substrate and the system of irrigation used.

These breeding techniques offer considerable advantages. The relatively short cycle and the fact that no highly-specialised manual labour is required result in considerable savings. Furthermore, the use of containers does away with the need for fields of a specific type and fertility as when such plants are grown outdoors following traditional methods. For the olive grower, growing plants in containers makes it easier to transfer the young plants from the nursery to the farm and then to the orchard, where the transplanting operations are simplified because the individual plants are easy to distribute. Furthermore, because the root system remains intact throughout transplanting, the plants undergo no crises and show quick vegetative recovery. In addition, they can be stored on the farm for as long as required before being planted.

The technological innovations described above are a valid incentive for nursery breeding, which in turn is important for the development of the sector, particularly in areas lacking in infrastructure, as is often the case in olive-growing countries.

Let us now examine the methods of indirect propagation.

Grafts on seedlings

This technique was used for the first time in Italy in nurseries in Pescia, Tuscany and has gained considerable importance in many olive-growing countries since the beginning of the century.

The first phase consists of obtaining seedlings. The seeds are collected from cultivars generally characterised by small stones and embryos with a high germinating capacity, usually in November – December. The stones are sown in a seed patch in the open, from the end of August to the beginning of September, on a germination bed consisting of sandy silt loam. Germination occurs about a month and a half later. Between April or May of the following year the seedlings are transplanted into another bed and, after a year, the plants are ready for the second phase, namely grafting.

Although it is possible to use any type of graft on olives, the usual technique applied on seedlings one to two years old is as follows.

Grafting takes place in spring when the sap is rising and the bark is slipping. The stocks are cut at about 5 cm from the ground, the bark is cut about 2 cm lengthwise and the cut is opened up; the graft, cut obliquely, is inserted with the cut side inwards facing the longitudinal cut, between the bark and the central trunk. The graft is prepared from one-year-old branches of average vigour, 4-5 mm in diameter, and consists of two internodes, of which only the upper one has leaves that are cut in half crosswise. The stock and the graft are tied firmly together and the exposed surfaces are covered with grafting wax or a similar compound. The grafted plants are left in the same place for a year during which time a single stem is selected from the graft. They attain a height of 50-60 cm by the end of the season. The following spring they are planted in rows in beds where they usually remain for another year before they are sold. They are then taken from the ground and the ball of soil round the roots is wrapped in rice straw. The length and complexity of this technique are self-evident. Not only does it require highly-specialised manual labour but it also requires environmental conditions (average daily temperature, humidity, nature of the soil) that are not easily encountered. Furthermore, when the plant is sold, the roots are subjected to mutilation which has a negative effect on subsequent rooting and development in the field. In an effort to avoid these drawbacks, the final phase can be completed in pots. Finally, because seedlings are heterogeneous by nature, they may affect the growth and entry into production of the trees differently so, although they belong to the same cultivar, during the first few years the appearance will be different. To avoid this drawback, when grafted plants are planted out, the grafting point should be covered with earth to promote the formation of adventitious roots, which may take place before the third year after planting.

Grafting of cuttings using clonal stocks

Some cultivars respond poorly to the rooting method both with mist propagation or in frames, because of their low or non-existent rooting capacity or because of their very precise seasonality. In such cases, an alternative solution to the problem is the grafting of cuttings using clonal stocks. This method was devised by the Italian Olive Cultivation Research Institute (CNR) in Perugia and leads to the obtention of grafted and rooted plants in a single operation. Clonal stocks are used.

Towards the end of the summer, a simple English-style graft is carried out on a horizontally-cut stock taken from yearling branches about 15-18 cm in

Olive harvesting in the Mediterranean area. (Photograph by Gianluca Boetti).

length, with two pairs of leaves; the scion has one or two nodes and one pair of leaves. Both pieces are of the same thickness after cutting. They are joined and tied together with a special tape which is self-adhesive and breaks spontaneously when the grafting point swells.

After treatment with rooting hormones, as with all cuttings, the grafted pieces are placed inside the frame, where the temperature and humidity conditions help the grafts to weld and the stock to take root. This takes about a month and the plants then enter the hardening phase. This technique makes it possible to obtain plants suitable for transplanting simply and economically within twelve to eighteen months.

As is the case with other fruit trees, efforts are being made to subject nursery breeding to more rigorous criteria, based on specific production disciplines, in order to obtain certified plants which guarantee varietal conformity and ensure good plant health and quality in terms of high rooting capacity, quick sprouting, uniform growth and rapid development.

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Chapter 4

PRODUCTION TECHNIQUES

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PRODUCTION TECHNIQUES

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The olive tree is a characteristic species of the Mediterranean basin and has only relatively recently been cultivated in other parts of the world with similar climates.

The three outstanding features of the species are its hardiness, longevity and attractive appearance, and ancient trees and centenarian orchards flourish to this day. Olive trees tolerate all sorts of terrain and are sometimes found growing on infertile ground and on slopes exposed to constant erosion where other crops would never thrive. They are also to be found in dry, sometimes arid areas, where low rainfall and high evapotranspiration cause long periods of water shortage.

Their long life span has meant that situations have tended to be longstanding. Criteria which may have been correct when an orchard was planted have become out-dated with the arrival of new technical, economic and social conditions. Infertile, eroded soils have also had damaging effects on orchards. Varieties with relatively uninteresting features or low yields still survive despite unsuitable planting densities and poor pruning, and many trees either become overgrown with widely alternating bearing patterns, or remain undersized and weakly.

In such regions, olives are used but not exploited as a crop, and are only harvested in years when this is economically viable. The high cost of a low-yield olive orchard, in addition to the poor quality of the oil produced, limits competitiveness with other annual oil crops which employ high-productivity cultivation methods.

Well-tended cultivars growing in suitable soil with a relatively favourable climate demonstrate that olives can produce well and that poor soil and extreme climates are not ideal conditions, but are merely tolerated. As with any fruit crop, proper farming, fertilisation, pruning, pest and disease control and irrigation all contribute towards improving the results of the olive orchard and raise product quality. Although farming practices applied to marginal olive groves can help reduce the ill effects, the cost is often excessively high.

The co-existence of marginal olive groves and productive groves means that olive cultivation varies from one region to another, and there are even major contrasts within a single area. In most areas, oil production is a basic source of labour and income for many communities, a social factor which must not be overlooked.

New orchards should be designed to give maximum revenue and to take maximum advantage of the technical resources available. It is at this stage that a viable production structure has to be established, based on favourable soil and climate conditions which, if necessary, can be corrected by providing additional water. The choice of cultivar, of plant material, the spacing between trees and their training are all factors to be taken into consideration so that mechanical farming methods can be used, in addition to methods aimed at increasing yields, improving the quality of both the olives and the oil, and producing enough to compete with other vegetable oils on the market.

The basic characteristics of the cultivation techniques to be used to give optimum revenue are described below. Since this Encyclopaedia cannot attempt to give full details of these techniques, bibliographical references have been given where possible, from which further information can be obtained.

PLANNING A NEW OLIVE ORCHARD

The goal of every orchard is to obtain maximum profits. In order to achieve this, the production system must ensure that the environment (soil/climate/water supply) gives maximum yields with minimum production costs and that all operations can be mechanised, especially harvesting. It is always a mistake to establish an olive orchard in an area with limitations since it will inevitably end up being a marginal orchard.

The essential factors involved in designing an olive orchard correctly are as follows: density and variety to be planted, the use of pollinators, plant material and training systems. Readers should refer to the classic olive-growing reference books for information on the preparatory work required prior to planting, fertilisation, weed management, tillage, irrigation and growing techniques during the first years.

CHOICE OF CULTIVAR

The genetic features of the cultivar determine its resistance or susceptibility to adverse soil conditions or climate, pests and disease, early production, the quantity and quality of the harvests, alternate bearing, date of ripening and suitability for mechanical shaker harvesting.

A single variety should never be used in larger orchards. It is more practical to use at least three varieties with progressive ripening seasons in order to

Panoramic view of a young olive orchard suitable for maximum mechanisation. The trees are cv. Picual and are 2 years old. Stakes are used to keep the single trunks upright.

rationalise farming and allow harvesting to be programmed so that machinery can be used over longer periods. The risk of meteorological accidents and variations in crops from year to year is also reduced.

The aim should be to achieve early bearing with high yields. Not all varieties meet this requirement but in Andalusia the Picual, Arbequina, Manzanilla and Koroneiki cultivars have given the best results.

The variety of cultivar is very important in terms of the type and quality of the oil produced (Uceda and Hermoso, 1994) and the type of oil to be produced will depend on the market for which it is presumably destined.

To ensure the success of an orchard the predictable vigour of the cultivar and planting density should be considered together, and high densities with vigorous cultivars should be avoided.

Although olive orchards should never be planted in limiting conditions, the varieties used should not only be productive but should grow well in adverse soil conditions. Cordeiro et al. (1992) list the following cultivars as tolerant to chalky soil: *Picudo, Cobrançosa, Galega, Lechín de Sevilla, Lechín de Granada* and *Hojiblanca* while *Picual, Arbequina, Lechín de Sevilla, Cañivano* and *Nevadillo* tolerate saline soils under controlled conditions (Benlloch et al., 1994). It is also worth analysing a cultivar's resistance to cold when weather conditions make this a necessary precaution. Observations made by Fontanazza and Preziosi in Perugia after the frosts of February 1967 showed that the following cultivars were highly resistant to low temperatures: *Carboncella, Casaliva, Cellina, Coratina, Leccio del Corno, Moraiolo, Passalunara, Ascolana, Carmelitana, Itrana* and *Verdale*. Susceptibility to certain plant health problems should also be taken into consideration, such as *Verticillium dahliae*, which Arbequina seems to tolerate well, whereas Picual is very sensitive to it, or *Cycloconium oleaginum*, which *Lechín de Sevilla* tolerates while *Picholine Marocaine, Meski, Picual, Hojiblanca, Gordal* and *Manzanilla*, as well as other varieties, are highly sensitive to it.

Under special conditions, another possibility is the use of rootstocks for grafting, since these can alter the variety's vigour (Fontanazza et al., 1002),

Olive orchard with drip irrigation, cv. Picual and plant density of 8 x 4m. Single-trunk trees grown from hardwood cuttings, the typical method of propagation in Andalusia.

sensitivity to pests (Rallo and Cidraes, 1975), tolerance to *Verticillium dahliae* (Hartmann et al., 1971), or resistance to frosts (Charlet, 1975, quoted by Loussert and Brousse, 1980).

USE OF POLLINATORS

Low yield problems may arise in orchards with cultivars that are not totally self-compatible or are incompatible if there are no pollinators (Chaux, 1959; Lavee and Datt, 1978). Pollinators are not commonly used in Spain, and there are large areas of highly productive single-variety olive orchards (in the province of Jaen, and in the south of the province of Cordoba), in contrast to information from other countries where pollinators are recommended. Several authors maintain that some cultivars benefit from cross-pollination (Morettini, 1972; Griggs et al., 1975; Fernandez Escobar and Gomez Valledor, 1985; Baratta et al., 1986; Baldini, 1992), although differences in behaviour in the same variety were reported in different areas and different years (Cuevas, 1992).

The lack of interest in pollinators in Spain may be due to the fact that many of the Spanish varieties are considered self-compatible (Riera, 1950; Fernandez Bolaños y Frías, 1969; García et al., 1975), and because a certain percentage of the trees is inevitably placed at random and by accident and they probably provide sufficient pollen to ensure adequate yield. Fernandez Escobar and Rallo (1981) found no differences in fruit set in six Andalusian varieties when pollen from another variety was applied. Suarez et al. (1984), however, recorded an increase in fruit set in the Manzanilla variety as a result of cross-pollination although this did not occur with Arbequina.

In years when pollination takes place at high temperatures, a high rate of sterility can be observed in single-variety orchards (Baldini, 1992), and this can be corrected using pollinators. Cross-pollination is essential in varieties with anomalies in their reproductive organs. According to Griggs et al. (1975) and Fernandez Escobar and Gomez Valledor (1985), cross-pollination can help reduce the percentage of parthenocarpic fruits.

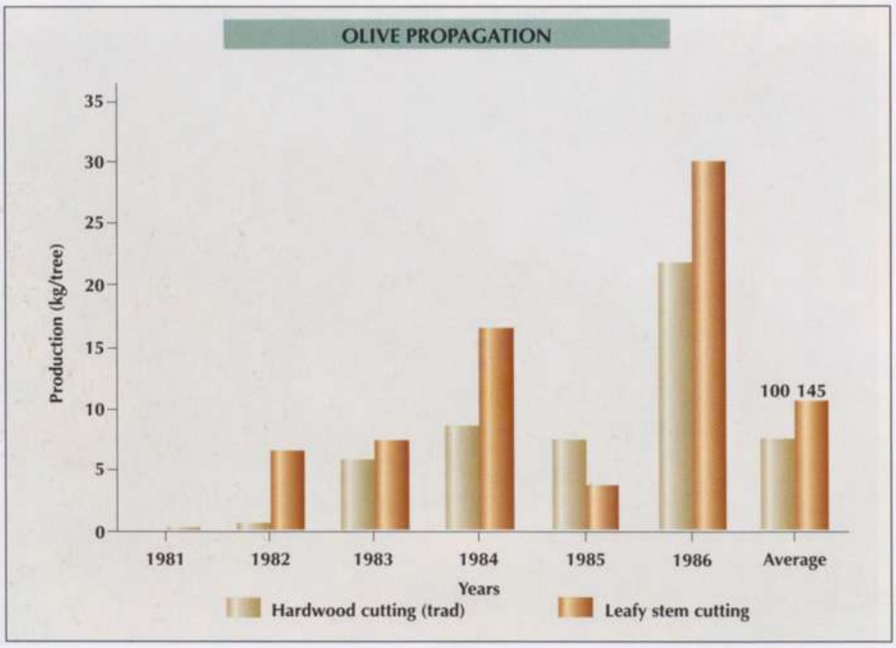


FIGURE 1. Olives propagated from self-rooting leafy stem cuttings started bearing earlier and with greater yields during the initial years than trees from hardwood cuttings which is the traditional method of propagation in Andalusia. The data are taken from an orchard planted in 1979 with 312 olives/ha, cv.Picual, on the «Las Morras» estate in Montalbán (Córdoba).

When designing an orchard, it is often wise to combine two or three infertile varieties with similar flowering periods, and to include 10% as pollinators. Minimum distances of 30 metres are recommended between the bearing variety and the pollinator (Sibbett et al., 1990).

PLANT MATERIAL

The plant material used is highly important as it influences early bearing, the future health of the orchard and the training of the trees. Figure 1 gives an example of how the type of plant used affected yields in the olive orchard during the first five harvests. Plants propagated in nurseries from self-rooting leafy stem cuttings under mist came into production a year earlier than plants obtained from hardwood cuttings self-rooted in nurseries, a traditional system in many olive regions.

Olives should be trained in nurseries with a single trunk with no low shoots in order to facilitate training in the orchard.

PLANT DENSITY AND LAYOUT

When water and nutrients are available in sufficient quantities, light can also be a restricting factor affecting yield and quality. It is essential that trees should have a maximum leaf surface receiving as much sunlight as possible. This can be achieved through correct plant density, optimum positioning of the plants on the plot and appropriate training and fruit production pruning.

In traditional olive growing, widely-spaced planting patterns are normal with densities almost always below 100 olives per hectare. Whereas very low densities have been used in extremely arid regions (in Sfax, where rainfall is below 200mm/year, the planting pattern is 24x24m), in rainy regions or irrigated areas high-density plantations are traditional, such as those in Sierra de Gata-Las Hurdes (Spain) where, with rainfall levels of above 700mm, orchard densities exceed 300 olives/hectare.

Scaramuzzi (1967) and Morettini (1967) recommended the use of higher densities than usual as a means of achieving increased yield. However there is some doubt as to the recommended density for each environment. Few studies have been published on planting densities but those that exist have almost always pointed out the problems arising with excessively high densities (Psyllakis et al. 1981; Villemur (quoted by Tombesi, 1988); Klein, 1993).

Tree density in dry farming

In Andalusia three long-term field trials (17 years) were performed on tree densities in dry oil olive orchards, with an average annual rainfall of 500mm (Pastor and Humanes, 1991), and densities of between 100 and 400 olives/hectare were compared. Average yield (Figure 2) tended to be higher when tree density was increased, although in one of the tests in the 400 olives/hectare density a small fall in yield was recorded. No significant differences in oil yield or fruit size were observed in any of the three trials or years.

In the last four harvests (Figure 3), a fall in yield at the 400 olives/hectare density was recorded, whereas at densities ranging from 100-312 olives/hectare, yields increased in proportion to tree density.

For densities of 312 and 400 olives/hectare, a square pattern (5.66x5.66m and 5x5m) and a rectangular pattern were studied. At the 400 oli-

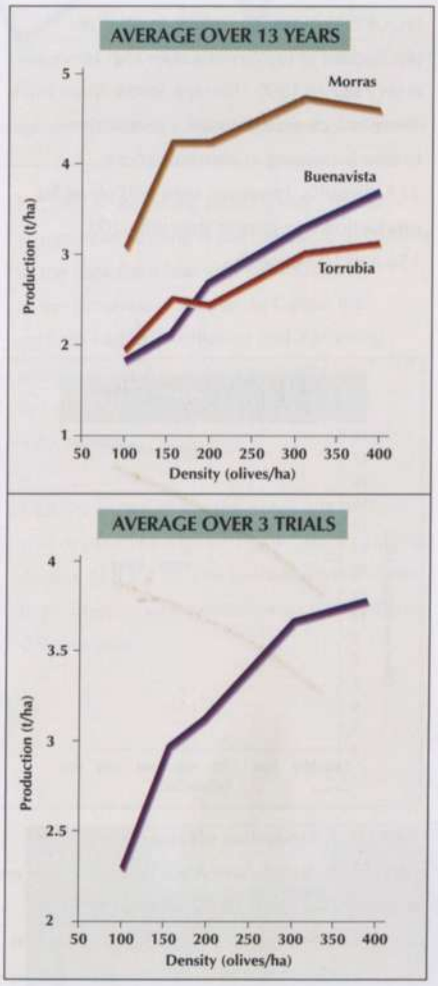


FIGURE 2. Above: average production of olives per hectare in dry farming over the 13 years of the test from 1978 to 1990 on each of the three farms studied. Below: average production for the three trials. An upward trend in production can be seen as planting density increases although, above 300 olives/ha, the increase is smaller.

ves/hectare density, the rectangular pattern gave higher yields in all three trials than the square pattern, which would suggest that there is more efficient use of sunlight when rectangular patterns are used for high densities.

It would appear, therefore, that higher tree densities than those traditionally used can be used on dry land, as long as the optimum canopy volume is respected. In these conditions a larger number of small-sized trees increases the fruit bearing surface, and consequently the yield. In conditions similar to those of the trials, a density of between 200 and 240 single-trunk olives per hectare is recommended, equivalent to the traditional 70-80 three-trunk olives/hectare commonly found in Andalusian olive orchards. A 7-8 metre space between rows helps mechanisation. In situations unlike those of the trials, and particularly in arid regions, similar experiments to those performed in Spain should be carried out if growers are to have access to reliable recommendations.

The possibility of using clonal rootstocks to reduce the vigour of the cultivars grafted onto them (Fontanazza et al., 1992) would enable tree densities higher than those recommended above to be used. Another possibility would be the use of erect varieties with compact growth (Lavee et al., 1986).

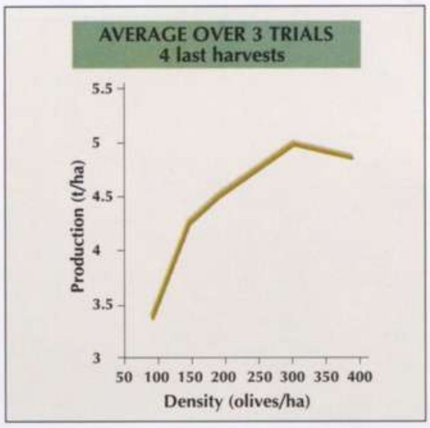


FIGURE 3. Average production of olives per hectare in dry farming over four harvests from 1987 to 1990. Average for the three trials. There is a clear tendency for production to stop increasing at densities above 312 olives/ha. However, with 400 olives/ha production was greater than with 200, 156 and 100 olives/ha.

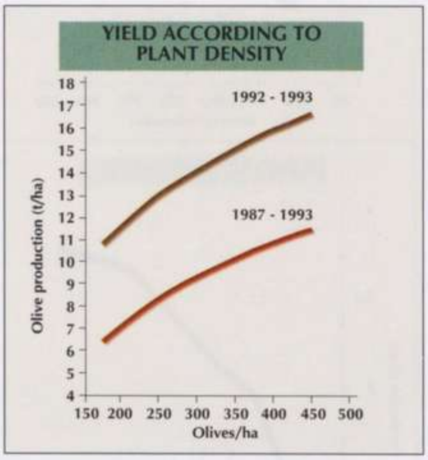


FIGURE 4. Production obtained in a test on planting densities carried out in Cordoba on an irrigated olive orchard planted in 1984 with the Arbequina variety using densities between 200 and 450 olives/ha. Both average production (1987-1993) and the average for the last two years (1992-1993) increased with higher planting density so that on irrigated farms, as long as tree development is controlled, higher planting densities can be used than in dry farming.

Tree density on irrigated land

In a field trial on tree densities under drip irrigation in Cordoba (Spain), densities ranging from 200 to 450 olives/hectare were studied. Average production per hectare in the first seven harvests (Figure 4) increased in proportion to tree density, with yields of between 6 and 12 t/hectare. In the last two harvests observed, equally large harvests were obtained with the highest tree densities, with average yields of between 11 and 17 t/hectare, while no differences in oil content or in average fruit size were observed.

Eleven years after plantation, once optimum yield volume per hectare was exceeded, trees began competing for light due to the excessive spread of the canopies. In the more poorly-lit areas, intense defoliation, low production, small fruit, delay in ripening and plant health problems (mainly *Cycloconium oleaginum*) were observed, although the highest yields were still to be found with the highest tree densities.

On land with unlimited water supplies, 300 olives/hectare are recommended, although in the short term yields tend to be much higher with 400-450 olives/hectare. Lanes should be 8 metres wide in a north to south direction. On irrigated land, several authors (Psyllakis et al., 1981; Klein, 1993) have observed that there is no improvement in yields in densities higher than those mentioned above, and management of the orchard is severely hampered.

Reducing initial density in intensive high-density orchards

When designing an orchard, high tree density can be used initially and subsequently reduced by half by pulling up alternate trees, after ensuring that the yield obtained has paid off the cost of the orchard (Fontanazza, 1984). The Italians refer to this as the *dynamic planting pattern*, although opinions about this technique vary (Tombesi, 1988).

The feasibility of this practice has been the subject of experimentation. Figure 5 shows the results of two trials and the questionable success of this method, particularly in irrigated orchards in which, over the 4-year trial pe-

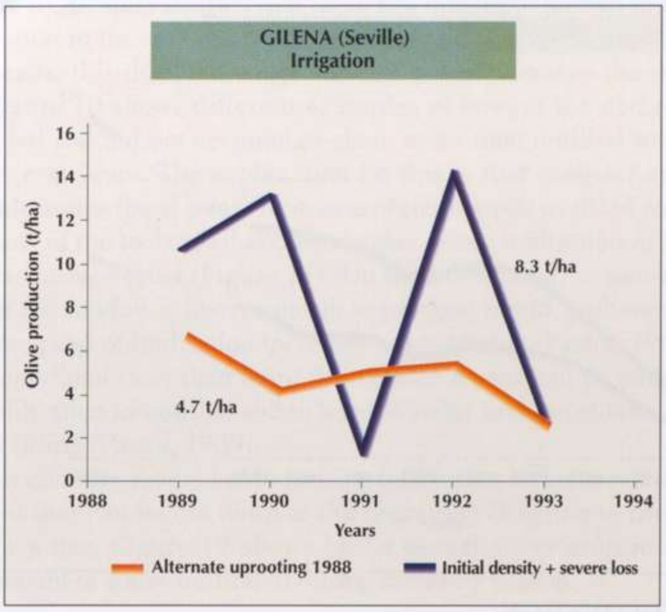


FIGURE 5. Reducing initial density by half in intensive farming is not profitable according to the data from two tests carried out in the province of Seville. In Gilena the orchard had drip irrigation and a planting density of 9 x 3.5 m. When density was reduced average losses in yield were 3.6 t/ha/year.

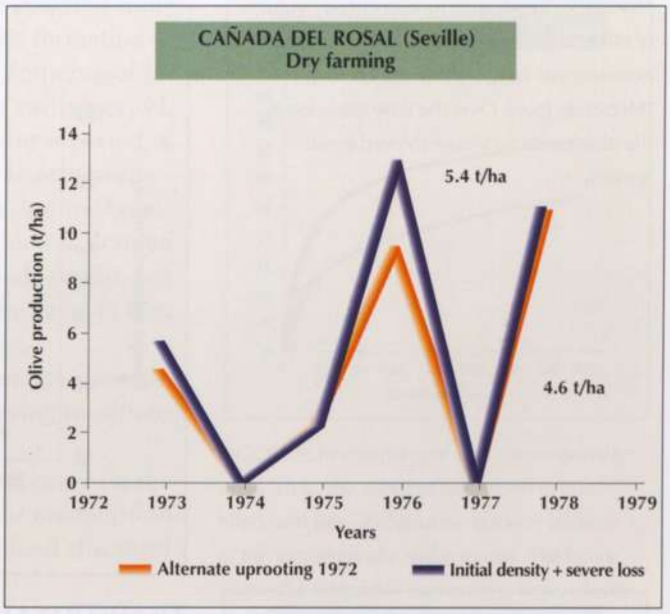


FIGURE 6. In Cañada del Rosal, the orchard was dry-farmed with cv. Picual and a planting density of 8 x 4 m. The average annual drop in production when density was reduced was 0.8 t/ha/year.

riod, an average of 3 t/hectare and year were lost after initial density was reduced by half. Severe regeneration pruning seems preferable.

TRAINING IN INTENSIVE ORCHARDS

Single-trunk olive trees should be grown in nurseries with 2 or 3 branches about 1 m above the ground to facilitate full mechanisation. These scaffold branches and secondary branches should form a free vase shape requiring just light pruning during the first few years. Page 176 gives more detailed information on this.

SOIL MANAGEMENT SYSTEMS

SOIL MANAGEMENT TECHNIQUES

Information available today indicates that traditional tillage is not suitable for olive orchards. It is impossible to recommend a specific cultivation system without first carrying out a preliminary study of the characteristics of the soil and the local climate. The most suitable system is possibly a combination of several systems, which may even entail using different systems for different plots on a single farm, concentrating on their advantages rather than on their many drawbacks.

The cultivation system selected should basically comply with the following requirements: a) optimum use of rainwater, the principal constraint in olive orchard production; b) maximum land use; c) soil conservation, preventing erosion, and d) facilitation of the different cultural care operations, particularly harvesting.

In most Mediterranean olive regions, rain is the only water the orchard receives. Annual rainfall is highly seasonal with a totally dry period (July - September) and a period of rainfall in autumn and winter during which almost 75 to 100 percent of the total annual rainfall occurs. In spring and summer, olive trees take in most of their water requirements from the soil, and it is therefore essential that as much water as possible be stored in the soil by removing weeds and reducing losses through evaporation.

Erosion is one of the most serious problems in Mediterranean agriculture. Shown here are gullies caused by storm water in a tilled olive orchard. Non-tillage methods reduce soil loss through erosion.

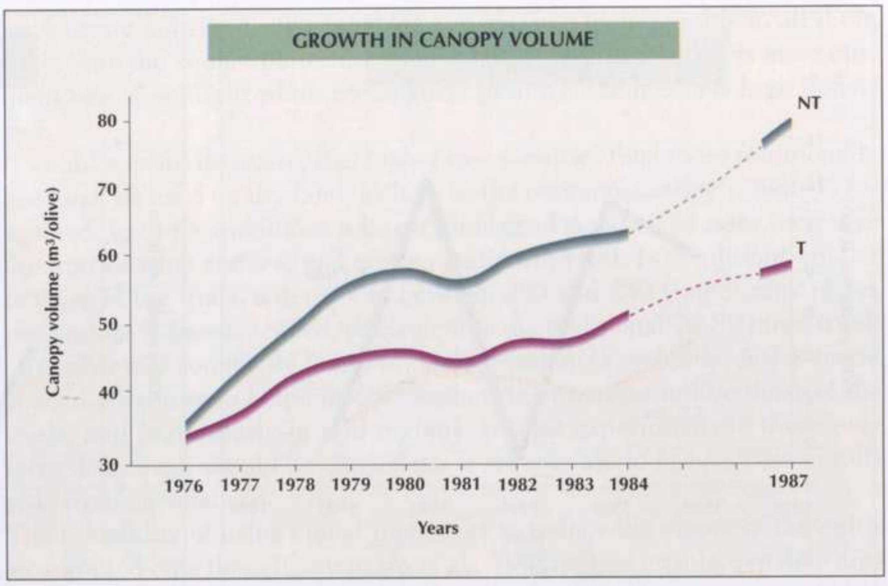


FIGURE 7. Trends over time in canopy volume of olives cultivated with no tillage or with conventional tillage. Venta del Llano estate (Mengibar, Jaén). Over the time considered, the olives with no tillage showed greater growth.

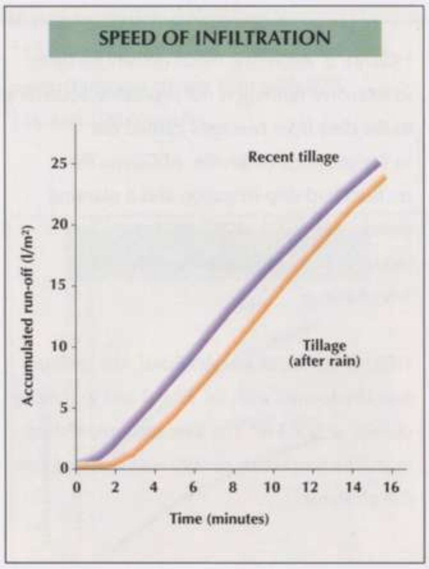


FIGURE 8. A fairly heavy shower reduces the speed of water infiltration into soil during subsequent showers unless new tillage breaks up the surface crust formed by the raindrops. The graph shows how the volumes of run-off generated by a storm were lower on recently tilled soil, especially during the 4 first minutes of rainfall, before the storm had altered the soil surface. The test was carried out in the field using a rain simulator giving a rainfall of 85 mm/h during 15 minutes. Finca La Mina (Cabra-Córdoba).

TRADITIONAL CULTIVATION

Tillage is the most frequent cultivation system used in olive farming, as the farmer seeks to increase water supplies. Many different types of equipment are used, the most frequent being the spring tine cultivator used in winter and spring to prepare the soil to allow water to infiltrate and to eliminate small weeds. This process goes no deeper than 15-20cm into the soil, while disking to a depth of between 15 to 25 cm is used in spring to remove large weeds. Finally, in summer, when the soil surface is totally dry, the land is harrowed or raked to break up the soil and fill in cracks to avoid water evaporation. Cultural care ends with the preparation of the soil for the olive harvest using a roller. Residual herbicides are often used under the canopy of the trees to keep the soil free from weeds during the harvest.

In total, the soil management operations for a medium-sized orchard require 8 to 12 70CV tractor hours per hectare.

CULTIVATION SYSTEMS AND WATER AVAILABILITY

Cultivation systems have an important influence on the balance of water in the soil and establish major differences in overall availability for the plant. High levels of infiltration are not in themselves sufficient as the infiltrated water must be retained.

The best indication of overall availability of water in the soil is the vegetative growth of the crop measured under conditions in which the lack of moisture is the main limiting factor. In these conditions, several woody crops frequently respond better in non-tillage situations than in tillage (Gras and Trocme, 1977; Pastor, 1990; Zaragoza, 1990). Figure 7 shows how olive trees cultivated in non-tillage conditions can, in time, achieve greater canopy volume than those tilled in a conventional manner, a sign of greater availability of water in the soil which in this case resulted in a major increase in yield.

Infiltration of water in the soil

Tilling apparently increases the speed of infiltration momentarily but the effect is not long-lasting since fairly intense rainfall on recently-tilled soil drastically reduces the capacity of infiltration in subsequent rainfalls (Figure 8). Despite the fact that there is a drastic reduction in the speed of infiltration in the soil surface (Figure 9) in untilled soils due to the formation of crusts, this does not mean that this practice makes the soil impermeable. Figure 10 shows different examples of how, at the end of a rainy period, tilled soil did not accumulate more water than untilled soil over a period of several years. The explanation for this is that compact and barely permeable zones (hard pans) form at a certain depth in tilled soils due to the effects of the tools used and this makes water infiltration even slower than on the surface crust (Figure 11). On the other hand, in non-tilled terrain, not all the rainfall is heavy enough to produce runoff, and once the crust is wet, the speed of infiltration increases considerably (Pastor, 1989).

Superficial (less than 5cm) tilling once a year can be sufficient to increase infiltration in untilled soil to levels similar to those obtained using traditional tilling (Pastor, 1989).

An effective method of improving infiltration is the use of plant cover on the soil that can be cut down at the beginning of spring to prevent competition for water. Figure 12 shows how a cereal cover crop increased the total amount of water infiltrated during the rainy season.

Ground water evaporation

Tilling has traditionally been considered to play an important role in the conservation of the water which has infiltrated into the ground, and it has been assumed that the reduction in evaporation is due to the capillarity having been broken up as a result of this practice. However, much of the experimental work performed in recent years fails to confirm this hypothesis. By the time the soil has softened sufficiently for it to be tilled, most of the water loss as a result of capillarity has already occurred. Figure 13 shows how tilling to a depth of 15cm in the month of March caused greater water loss through evaporation than in the untilled ground, and a difference can be observed both on the superficial layer and in deeper layers. The superficial crust in non-tilled ground can reduce the speed of evaporation.

Certain types of soil have a definite tendency to form cracks when the ground is not tilled, but it is also true that these cracks appear when the

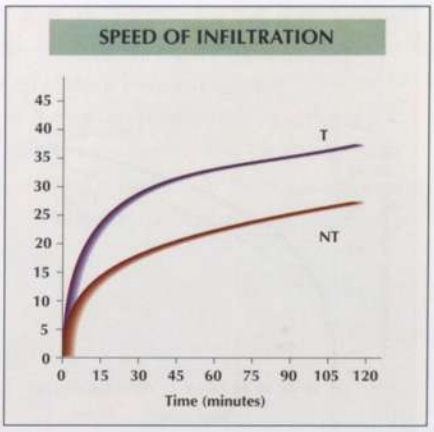


FIGURE 9. In comparison with conventionally tilled lands, the speed of infiltration in non-tilled land free of vegetation is lower because of the formation of a surface crust. The figure shows the infiltration curves for a limey-clayey soil in Santaella (Córdoba).

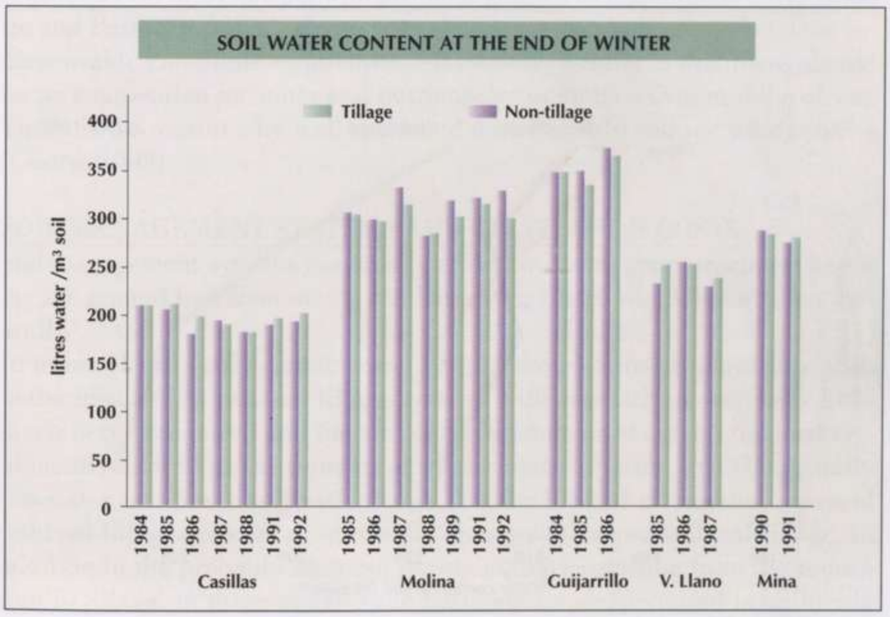


FIGURE 10. In Mediterranean areas almost 75% of total annual rainfall occurs during autumn and winter. The water stored during this period is consumed by the olive during the dry season. The figure shows soil water content at the beginning of spring in 5 tests and in different years, with Tillage and Non-Tillage. In spite of the lower speed of infiltration in NT (Figure 9), water availability with T and NT was not very different. The asterisks show cases in which the differences observed were statistically significant ($p<0.05$).

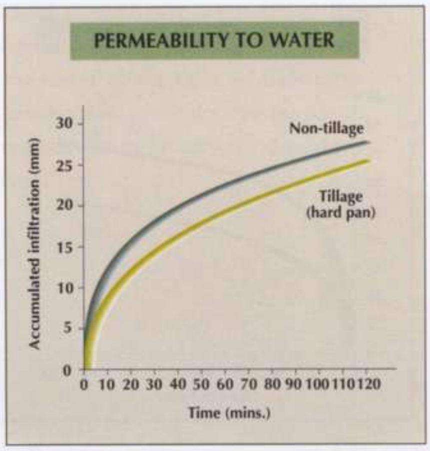


FIGURE 11. Compacted layers in the soil profile beneath the tilled surface layer known as hardpans are less permeable to rainwater than the surface crust present in non-tilled cultivated soils. The curves for accumulated infiltration were obtained in Santaella (Córdoba) in a soil with a limey-clayey texture.

water in the ground has evaporated, and they also form in tilled soil, for identical reasons. It is therefore doubtful whether there is any real benefit to be had from this practice, especially considering the additional cost involved.

EROSION

Erosion is one of agriculture's main problems, to the extent that more than a third of the Mediterranean agricultural areas are affected by it. In olive orchards in the province of Cordoba and in plots on slopes, annual soil losses ranging from 60 to 105 t/hectare per annum were observed (Laguna, 1989). The main cause of erosion in Mediterranean regions is water itself, although in some areas and soils, wind-related erosion is also a major cause.

Water-caused soil erosion involves a dual process: loosening of the soil particles as a result of the impact of rainwater, and the transport of particles with the run-off, which also drags along new particles as it runs downwards. This double process is affected by the cultivation system used.

Most authors who have studied erosion problems agree that covering the soil with vegetation is the most efficient way to reduce erosion (Phillips and Young, 1979; Blevins, 1986). The cover has several functions. It reduces the extent and intensity of the impact of rainfall on the soil, increases the speed of rainwater infiltration into the ground and reduces the speed of run-off. Figure 14 shows how vegetative cover reduced soil loss to zero, while erosion was most intense in freshly tilled ground. This figure also shows how there was a lot less erosion in non-tilled soil than in tilled ground. Greater soil structure stability against the impact of rainfall could explain why there was less loss of soil in ground surfaces not disturbed by tilling (Castro, 1993). This does not mean that non-tilled ground is the perfect solution in the fight against erosion since, on large farms and on sloping terrain, when rainfall is very heavy gullies may form in the natural drainage areas.

SOIL MANAGEMENT AND PRODUCTION SYSTEMS

Field trials were carried out during several years in Andalusia using the non-tillage technique as an alternative to conventional tillage. In the non-

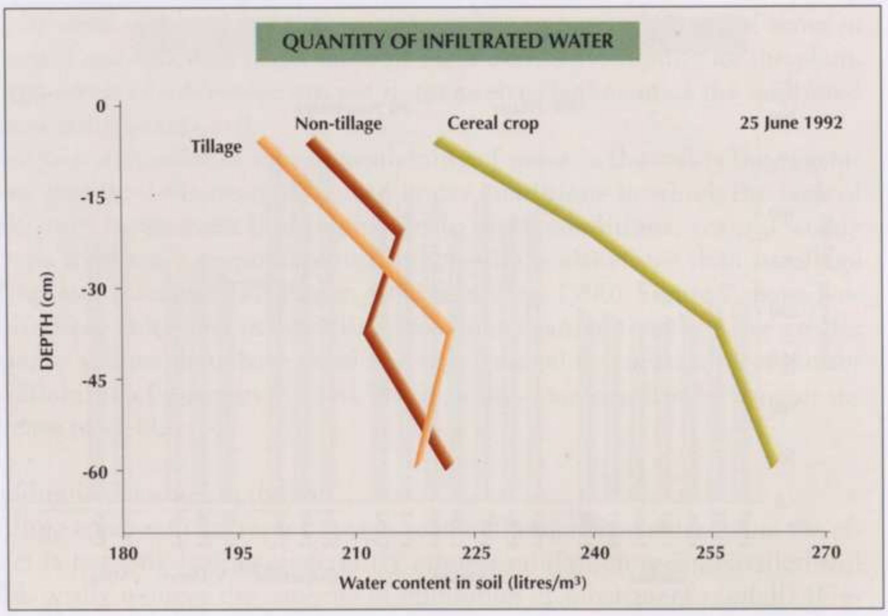


FIGURE 12. The use of live cereal cover which is chemically harvested using gliphosate at the end of March showed a significant increase in the quantity of water infiltrating the soil during a period of rainfall of 110 mm, in comparison with conventional tillage and non-tillage systems with bare earth. Test carried out in Cordoba on soil with a clayey-loamy texture.

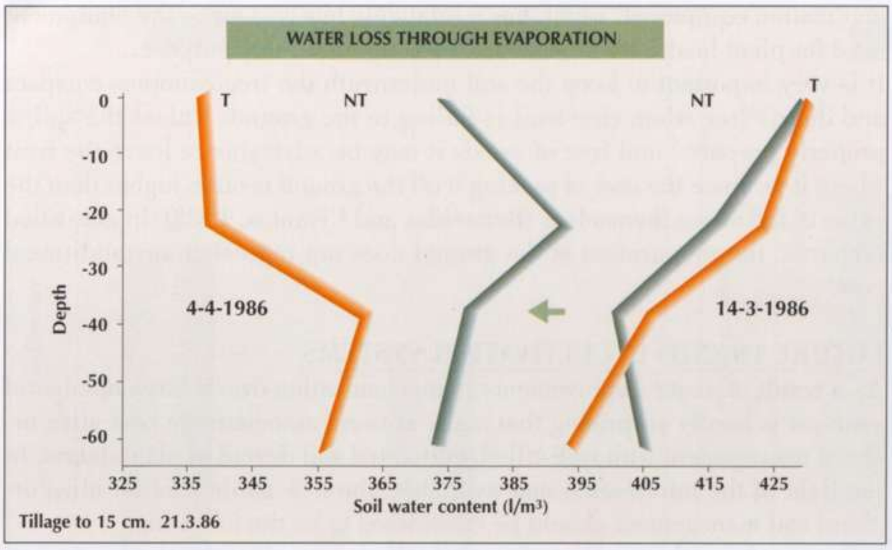


FIGURE 13. Tillage in spring may produce heavy water loss in soil through evaporation, even affecting deep soil layers. In NT, water loss through evaporation was much less than in T and non-tilled orchards had greater water availability during spring. The test was carried out in La Rambla (Cordoba) in a clayey-loamy soil.

tilled areas, the soil was not disturbed for four years and was kept free from weeds using residual weed-killers. These trials revealed that in a large number of cases the technique led to a major increase in productivity compared with traditionally tilled areas. Out of a total of 88 controlled trials, in which reliable information was available for periods of between four and twelve consecutive years (Figure 15), yields in non-tilled ground increased in 75 areas and dropped in only four. Out of a total of 88 trials, production in non-tilled ground increased by 16%.

Reduced tillage systems, both semi-tilled and minimum tilled, also gave increases in productivity compared with conventional tillage (Pastor, 1990), and these cultivation systems are commonly found in Andalusia today. In both these reduced tillage systems, residual herbicide is applied underneath the canopy of the trees and this area is left untilled, while mechanical tilling of varying degrees of intensity is performed along the centre of the lanes.

Plant cover cultivation systems can also be used, either with weed cover (Pastor, 1990) or by sowing with artificial grasses or leguminous cover (Castro and Pastor, 1991) which are very efficient in preventing erosion. One indispensable condition for obtaining satisfactory results is that there should be no competition for water and nutrients between the cover and the olives. There is no reason why well-managed cover should reduce productivity (Castro, 1993).

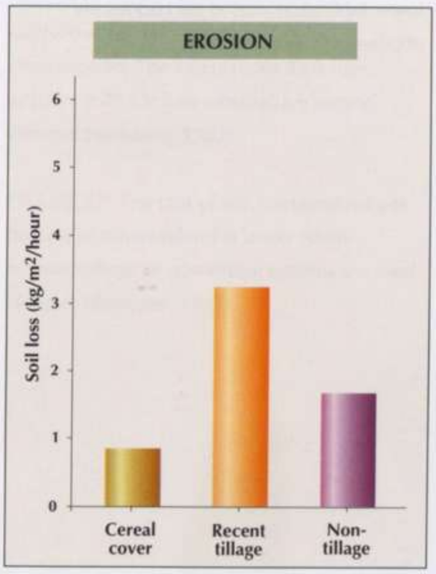


FIGURE 14. Cultivation methods have a great influence on soil loss through erosion. Although with NT run-off may be greater, soil loss was much greater in recently-tilled soil. The use of plant cover on soil reduced run-off and practically eliminated soil loss through erosion. The test was carried out in the month of October 1991 on dry soil using a rain simulator to apply a storm with an intensity of 85 mm/h during 15 minutes.

SOIL MANAGEMENT SYSTEMS AND CULTIVATION COSTS

Soil management systems essentially affect two cultivation practices: keeping the ground free from weeds and harvesting olives which have fallen naturally.

In terms of soil maintenance costs, both in the systems of non-tillage with herbicides and in reduced tillage systems with vegetative cover, very little machinery is required and the size of the tractors used can be reduced significantly as well as the number of tractor hours (Figure 16). This usually translates into lower cultivation costs (Figure 17) and means that zero and reduced tillage systems are generally cheaper than conventional tillage, in addition to the probable increase in productivity resulting from the reduction in tillage. In these systems the basic equipment required is herbicide

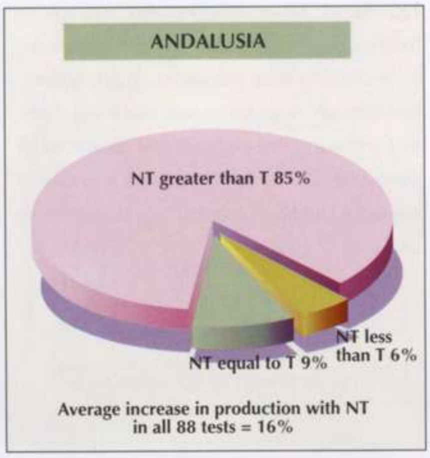


FIGURE 15. Summary of the results of the tests on soil management techniques carried out by various official organisations in Andalusia. Each of the tests referred to was observed for a minimum of four years. In most cases, the technique of non-tillage gave increased production in comparision with the conventional system. Poor weed control and lower infiltration caused the bad results obtained in five of the tests.

application equipment, which has a relatively low cost since the equipment used for plant health treatments can be adapted for this purpose.

It is very important to keep the soil underneath the tree canopies compact and debris-free when ripe fruit is falling to the ground. Unless the soil is properly prepared and free of weeds it may be advisable to leave the fruit where it is, since the cost of picking it off the ground is often higher than the value of the olives themselves (Benavides and Civantos, 1982). In non-tilled orchards, the preparation of the ground does not represent any additional cost.

FUTURE TRENDS IN CULTIVATION SYSTEMS

As a result of major improvements in mechanisation over a large number of years, it is hardly surprising that many growers associate the best olive orchard management with well-tilled, cultivated soil devoid of plant debris. In the light of the information now available, the new guidelines for olive orchard soil management should be considered to be the following:

- Cutting down the number of annual tillage operations to the bare minimum. More tillage does not mean more moisture, as long as weeds are kept under control.
- Surface tillage is the most advisable system leaving behind the largest possible amount of plant debris.
- Tillage should be performed at times when it will not cause extensive water loss from the soil.
- Maintenance of well-managed plant cover can help reduce erosion without having a negative effect on productivity. The application of low dosages of certain post-emergence herbicides can help keep cover development down to levels which are not harmful for the crop.
- Herbicides should be applied to completely eliminate weeds under the tree canopies but this is not essential in between rows.
- Herbicides must be applied correctly. If a weed escapes the control and turns into a problem, a different, more efficient active matter should be used. On no account should attempts be made to solve the problem by increasing the dosage of herbicide.
- The efficient application of herbicides is performed using equipment in good condition, particularly if the cost of the treatment is to be kept to a minimum.

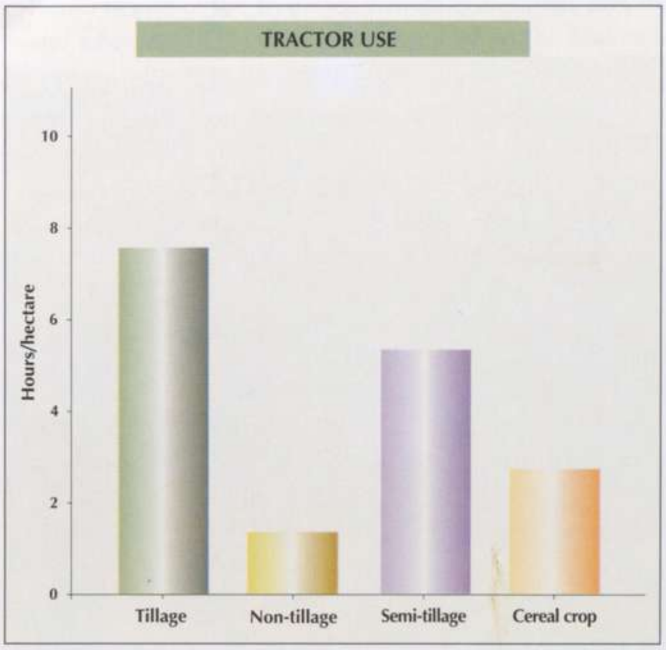
The recommendations given above for soil maintenance should not be viewed as incompatible, since different combinations may be used. Another important aspect is the reversibility between systems if for some reason a decision is taken to change one cultivation method for another. There is nothing to prevent changing tilled soils to non-tilled systems through the application of herbicides. The crop usually responds with a certain increase in vigour. However when doing the reverse process some care is required, and only superficial tillage should be performed initially, so that minimum damage is done to the roots.

A spring tine cultivator is often used for tilling olive orchards. Vertical tilling is preferable to using a disk harrow.

FERTILISATION

GENERAL CHARACTERISTICS

Correct fertilisation should cover the needs of the crop and provide the quantities of nutrients which cannot be extracted from the soil. Assessment



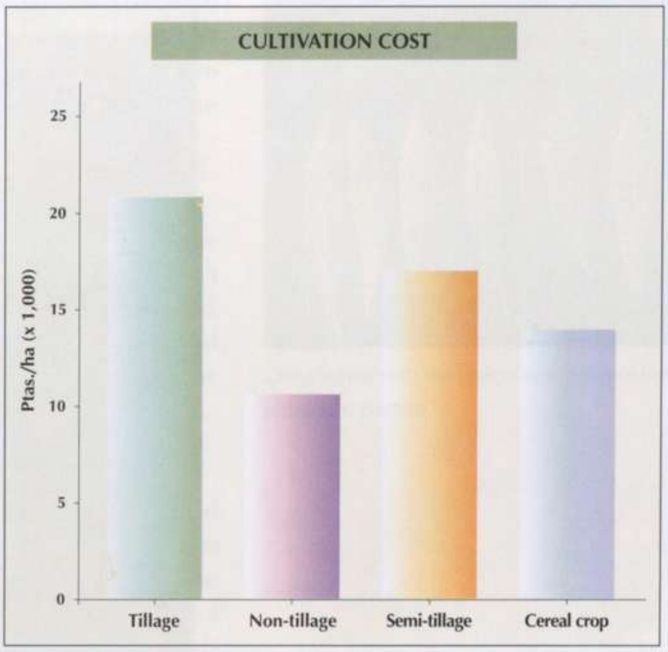


FIGURE 16. Reduced tillage, semi-tillage, non-tillage and cereal cover techniques reduce the number of tractor hours necessary for cultivation per hectare as well as fuel consumption. The calculations took into account a 70 CV four-wheel drive tractor. (Source: Humanes, 1992).

FIGURE 17. The cost of soil management per hectare of olive orchard is lower when reduced tillage or non-tillage systems are used. (Source: Humanes, 1992)

of soil deficiency and the crop's requirements is difficult but guidelines can be given which, with the necessary corrections, can help solve specific olive orchard fertilisation requirements. These guidelines should be deduced from the nutritional condition of the orchard.

THE IMPORTANCE OF NUTRIENTS IN OLIVE ORCHARDS

Sixteen elements are recognized as essential for the growth of plants: carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), sulphur (S), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), boron (B) and chlorine (Cl). The essential characteristic of these elements is that the plants cannot complete their life cycle without them.

The three non-mineral elements (C, H and O) account for approximately 95% of the dry weight of an olive, and are combined in the photosynthesis process when the plant forms the carbohydrates which are to be its main nutritive component. The remaining 5% is made up of elements which are important in fertilisation.

The thirteen mineral elements are classified as macronutrients (N, P, K, Ca, Mg and S) and micronutrients (Fe, Mn, Zn, Cu, Mo, B and Cl), depending on the concentrations required for correct fertilisation.

Nitrogen is the element to which the olive tree responds most swiftly and with the greatest benefits in that it speeds up and generally increases crop bearing. It increases the amount of chlorophyll as well as the plant's ability to assimilate other nutrients. Nitrogen is needed most from the period of flowering to the hardening of the pit. For specific quantities of water content in the soil, correct nitrogen fertilisation increases shoot growth and the number of fruits set per tree, thus increasing productivity. Nitrogen deficiency can be identified by the pale green colour of the leaves (which, however, do not become necrotic as they tend to do when suffering from other nutrient deficiencies) and by a general reduction in growth of the plant.

Phosphorus is an essential element in plant life. It is indispensable in cell division and in the development of meristematic tissues, and plays a key


On slightly sloping land, plantation that follows the natural contours helps to decrease damage by erosion.

role in the intermediary phosphoration and dephosphoration processes (Krebs cycle). It is also linked to the utilisation of starch and sugars, and to the photosynthesis leading to carbon fixing. P deficiency is rarely found in field conditions, but the symptoms are a major reduction in leaf size and intense greeny-purple colouring (Recalde and Chaves, 1975). Major P deficiency causes abnormally low N, Mg, Ca and B content, and B deficiencies can be detected when the P level is high (Loussert and Brousse, 1980).

Potassium is found mainly in the ionic-shaped cell vacuoles. It is very mobile and is necessary for the formation of nitrogen compounds and carbohydrates, in assimilation and respiration processes and in water movement within the plant. Potassium deficiency reduces resistance to cold and drought and increases sensitivity to cryptogamous diseases.

It is difficult to maintain adequate levels of K in olive trees, because more than 60% of the K in the plant is located in the fruit at harvest time, because of the low mobility of K in soils and the soil's ability to retain it, and because of the difficulty of extracting it from the soil at certain times (in autumn, owing to the low water content of the soil, or in winter owing to low ground temperatures which reduce the absorption of water and nutrients).

The first symptoms of potassium deficiency in leaves (Loussert and Brousse, 1980) start with chlorosis at the tip and progressive decoloration towards the basal area. When there is a major deficiency, the chlorosis causes necrosis of the leaf tissues, particularly in the older leaves due to their dehydration, and this later extends to the younger leaves. In cases of intense and long-lasting deficiencies, there is usually marked defoliation.

Olive trees are tolerant of calcium and very sensitive to calcium deficiencies. Olive orchard soil is usually rich in Ca and deficiency problems are not common. In very acid soils, levels of this macroelement have to be carefully monitored and liming is recommended.

Boron is one of the tree's least mobile elements and its deficiency (Recalde and Chaves, 1975) can be detected when the leaves become chlorotic and gradually turn paler green from the tip towards the basal area, until two thirds of the leaf blade is affected. Then the tip becomes necrotic and the leaf falls, with heavy defoliation in the event of severe deficiency. Correction of B deficiency is very important, as N and K supplies may be inefficient if limited by lack of boron (Klein and Lavee, quoted by Polí, 1986).

A characteristic feature of magnesium, too, is its low mobility. There is greater consumption of this element at bud growth in the spring, although Mg deficiency has seldom been identified in olive trees (Recalde and Chaves, 1975). The symptoms of Mg deficiency are seen when leaf content is below 0.08 per cent; the leaves of affected trees become chlorotic at the tip or the edges, while the rest of the leaf stays green.

Olive leaves with the typical symptoms of low potassium content.

NUTRITIONAL CONDITION OF THE PLANT

Of the different diagnostic techniques available, leaf analysis is the method which best defines the nutritional condition of the olive tree. This method is based on the fact that leaves are the main organ for the metabolism of the plant, so changes in the supply of nutrients are reflected in the make-up of the leaf and these variations are more pronounced at certain stages of development. The concentration of nutrients in leaves in specific growth states is linked to the general functioning of the crop (Bould, 1966; Fernandez Escobar et al., 1994). It is possible to determine by experiment the best position of the leaf to be tested, the best state of development to gain a true picture of the level of the nutrient, the best concentration of nutrients for optimum growth and production, and the nutrient levels in the leaf associated with deficiency and toxicity.

A graph linking the concentration of a nutrient in the tissues with the growth of the plant or its yield (Figure 18) would show up three differentiated areas (Fernandez Escobar, 1993): normal concentration area, moderate deficiency area, and area of severe deficiency. Response to fertilisation can only be expected when concentrations of nutrients meet these last two situations.

On the basis of this, Freeman et al. (1994) proposed a diagnosis chart (Table 1) establishing the critical levels of essential nutrients. Mineral content should remain stable during the period when samples are taken. The youngest leaves are full of nutrients and their composition varies, whereas the older leaves send out nutrients, the proximity of fruit may affect nutrient concentrations and they are also more liable to be affected by pathogens or other accidents. For these reasons, the leaves taken for analysis should be from this year's shoots, without fruit, picked from between halfway down the shoot and the base. They should be totally expanded and healthy, and aged between two and five months (Fernandez Escobar, 1993 quoting Chapman, 1966; Childers, 1966; Beutel et al. 1983). The best time for taking samples is during the summer when vegetative processes come to a halt (end of July in the northern hemisphere).

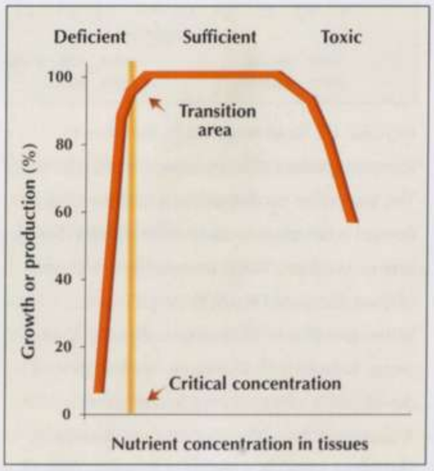


FIGURE 18. Link between nutrient concentration in leaves or in tissues and crop growth or yield (Fernández-Escobar, 1993).

FERTILISATION OF OLIVE ORCHARDS

Nitrogen fertilisation

Field trials in dry olive orchards performed in Andalusia (Ferreira, 1984) have responded to increased dosages of N for fertiliser levels of below 0.6

TABLE 1
CRITICAL NUTRIENT LEVELS IN OLIVE LEAVES
Collection of leaf samples: Month of July

Element	Deficient	Sufficient	Toxic
Nitrogen	1,40	1,50 – 2,00	
Phosphorus	0,05	0,10 – 0,30	
Potassium	0,40	over 0,80	
Calcium	0,30	over 1,00	
Magnesium	0,08	over 0,10	
Manganese		over 20	
Zinc ppm		over 10	
Copper ppm		over 4	
Boron ppm	14	19 – 150	185
Sodium ppm			over 0,20
Chlorine ppm			over 0,50

According to Freeman et al.., 1994.

kg nitrogen per olive tree (Figure 19), but only in plantations with a high productive capacity of around 35 kg/olive have responses to larger dosages of N been observed. As a result, in traditional olive orchards, supplies of between 0.5 and 1 kg of N/olive are recommended, depending on the level of productivity of the orchard. This should allow an adequate level of N to be maintained in the leaves.

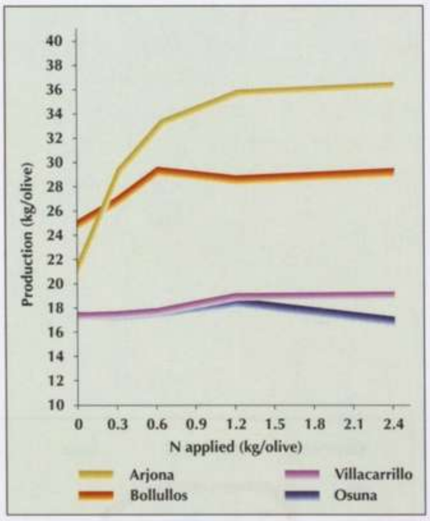


FIGURE 19. Yield response in the olive to increasing doses of nitrogen applied to the soil. The tests were carried out in a traditional dry-farmed adult olive orchard in Andalusia (Ferreira and co-workers, 1984) on estates in: Manero (Arjona-Jaén) cv. Picual, during 11 years; Villarejo (Villacarrillo-Jaén) cv. Picual, during 7 years; Rebujena (Bollullos de la Mitación-Seville) cv. Gordal, during 5 years; and Maturana (Osuna-Seville) cv. Lechín Ecijano, during 11 years. A significant response to N applications was only observed in the tests in which the olives had a good level of production. Under these conditions, the recommended dose should be between 0.6 and 1 kg/olive of N.

In California, Hartmann et al. (1986) failed to obtain response to N administration when the leaf content remained at adequate levels, whereas administration in trees with N deficiencies proved to be very beneficial. These authors recommend a maintenance administration in autumn of 1 kg N/olive tree, as long as the leaf content stays above 1.5%.

In olive orchards using drip irrigation, Dominguez (1993) proposes continued application of N from February to August, with monthly applications of 2%, 5%, 10%, 25%, 35%, 15% and 8% respectively, In dry orchards, there are no advantages to be had from fractioning nitrogen supplies, and a single application in winter is recommended, preferably in ammonia or urea form (Ferreira, 1984).

In arid regions (Kechua and Tnani, 1978) and in drought years (Ferreira, 1984), lack of response to nitrogen fertilisation is common. Figure 20 gives details of a field trial performed by Ortega Nieto (1964) over a 15-year period in Jaen, where response to N manuring was only observed in years when the rainfall exceeded 500 mm. In these conditions it is preferable to use foliar fertilisation, a technique which is equally useful in any type of olive orchard, even in orchards under irrigation.

Urea is the nitrogen fertiliser that is most quickly assimilated by the leaves. It is rapidly absorbed and metabolised by the plant and rapidly transported to the foliage, inflorescences and fruits during the growing period (Klein and Weinbaun, 1984). When applications are repeated, high leaf levels of N can be maintained throughout the vegetative cycle (Ferreira et al., 1978). Foliar application of urea has a positive influence on production, increasing the rate of fruit set and reducing olive drop after setting (Cimato et al., 1990). The best dosages of urea for foliar spraying range between 4 and 6%, since higher concentrations tend to produce leaf burns, although the trees recover subsequently (Ferreira et al., 1978).

Foliar applications of urea can result in larger increases in productivity per fertilised unit than when applied to the soil (Figure 21), although if the soil is fertilised with N, there is usually no profitable response to foliar fertilisation using urea.

Phosphorus fertilisation

Productive responses to fertilisation with P in olive orchards have seldom been recorded (Hutter, 1970; Recalde, 1970, reported by Ferreira, 1986; Ferreira, 1984). When a response was observed, the application had been applied for three or more consecutive years but it was not economically viable in any of the cases studied.

The possible reasons for the poor response of the olive trees to P supply may be the plant's low consumption or the fact that the root system of this species is very mycorrhizal (Sbrana and Vitagliano, 1990; Baldini, 1992), as a result of which, in average soil conditions, the root system may be able to extract its P needs for the life span of the plant. Applications of P are recommended when a foliar analysis performed in July detects deficiency levels.

Foliar fertilisation with P can give interesting results. In traditional olive orchards in which tree volume is approximately 80 m*3*, 30-40g of P/tree can be sprayed on using phosphoric acid or monoammonic phosphate (Hermoso and Morales, unpublished). In trees with sufficient leaf content of P, no response has been obtained from foliar application of increasing quantities of P (Provincial Delegation of the Jaen Board of Agriculture, unpublished).

Potassium fertilisation

Few potassium fertilisation soil trials have shown a clear response to fertilisation (Recalde and Chaves, 1975; Ferreira, 1984). Major increases in yields have only been observed in olive orchards with a high level of deficiency in K when huge quantities of potassium sulphate (Hartmann et al., 1986) were applied to the soil.

In olive orchards using drip irrigation, fertirrigation techniques may be used, applying continuous supplies together with the irrigation water. Dominguez (1993) recommends 15% applications of K in spring, 35% in summer, and 50% in autumn, when the fruit is ripening.

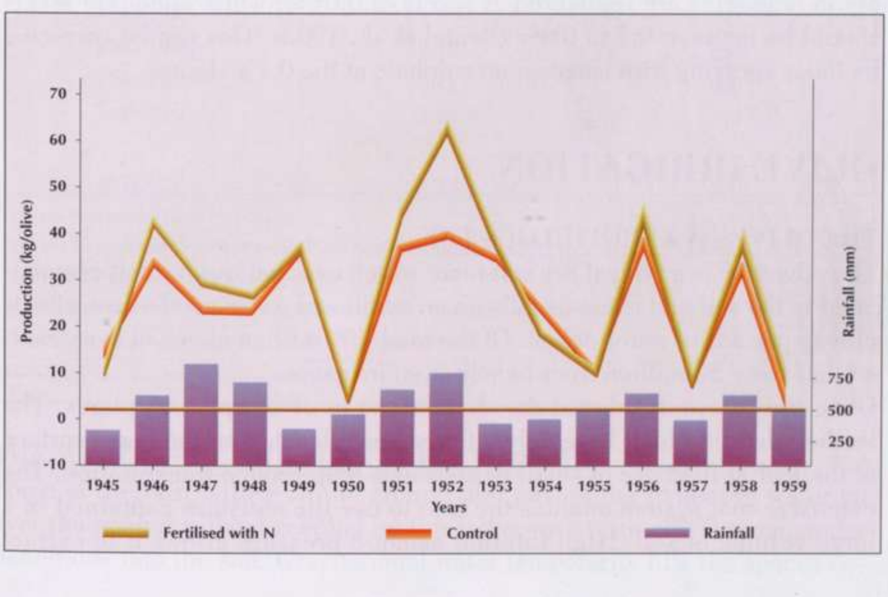


FIGURE 20. The response of the olive to nitrogen fertilisation depends on soil water availability. The figure shows yield in a test carried out during 15 years on the Los Naranjos estate in Jaén in a traditional dry-farmed olive orchard with cv. Picual trees 60 years old. The trees fertilised with N received annually 2 kg of ammonium sulphate per olive. During the test as a whole, the olives treated with N produced 3.9 kg more per tree than those left untreated but differences in production were only observed in years in which rainfall exceeded 500 mm (Ortega Nieto, 1964).

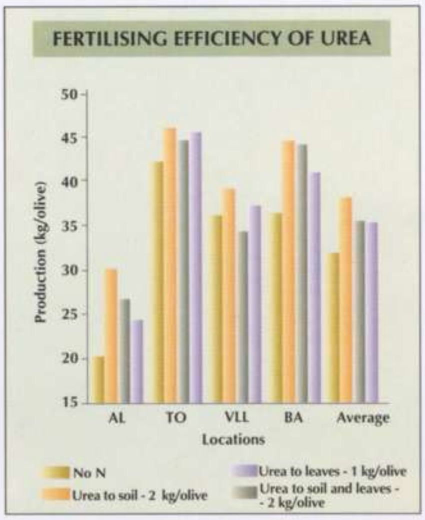


FIGURE 21. Study of fertilising efficiency of urea applied using different methods and dosage. The figure shows average production of olives in 4 5-year tests in adult dry-farmed olive orchards with cv. Picual in Alcaudete (AL), Torredonjimeno (TO), Villacarrillo (VLL) and Baeza (BA) in the province of Jaén (Hermoso and Morales, personal communication). Application to the soil of 2 kg/tree was the method showing the greatest increase in production whereas two applications to leaves per year of 500 g/tree was the treatment which gave the greatest increase in production per unit of fertiliser applied. When soil is fertilised with urea, leaf fertilisation is not apparently efficient.

Foliar fertilisation using K can be extremely useful in olive orchards. Potassium nitrate is the best-assimilated salt and has proved to be more efficient than potassium sulphate (Hermoso and Morales, unpublished; Perica *et al.*, 1994). Spraying with urea immediately before spraying with NO_3K increases the absorption of K and N through the leaf (Perica et al., 1994). Figure 22 shows an example of adequate long-term responses to foliar applications of 5% potassium nitrate in trees with clear signs of deficiency and low levels of K in their leaves. The average yield of the olive orchard under treatment increased by 23% in comparison with non-sprayed trees, although the response was not noticeable until the third year of consecutive application (Hermoso, personal communication). In trials where the trees had adequate potassium levels in their leaves (over 0.8%), no response to increased supplies of foliar application of K were observed (Provincial Delegation of the Jaén Board of Agriculture, unpublished). Foliar application of potassium nitrate is recommended using concentrated solutions of 2-3% when the total amount of liquid applied is 1,000/ha.

Correction of deficiencies in other elements

Boron and magnesium are microelements which are frequently responsible for deficiencies in olive orchards. Lack of iron can cause iron chlorosis in very chalky soils and should be corrected by the use of chelates or iron sulphate injections into the tree trunk (Navarro et al., 1992). Manganese and zinc deficiencies can be corrected by spraying leaves with chelates of both microelements or using commercial multivariant correctors rich in Mn and Zn.

Boron, along with nitrogen, is one of the nutrients which the olive tree responds to most quickly, despite the fact that this element is one of the least mobile inside the tree (Recalde and Chaves, 1975). According to Hansen (reported by Recalde and Chaves, 1975), beneficial response to boron application for leaf contents of below 19 p.p.m. is obtained. The correction of deficiencies can be achieved by soil application of 40g boron/tree in the first year, and annual maintenance dosages of 25 g/tree. Another possibility is foliar application, and this is recommended in combination with the two anticryptogamous treatments, at a dosage of 0.5% of a soluble formula containing 20.8% B.

Mg deficiencies are registered at levels of 0.07%, while adequate levels should be between 0.1 to 0.6% (Beutel et al., 1983). This can be corrected by foliar spraying with magnesium sulphate at the 0.7% dosage.

OLIVE IRRIGATION

THE OLIVE - A XEROPHILOUS TRE

The olive tree is a typical dry soil plant which uses natural rainfall accumulated in the soil and is not usually given additional water to offset the effects of long periods of water deficit. Of the total 750 million olives, it is estimated that some 50 million trees benefit from irrigation.

Olive trees have developed the characteristics of xerophilous plants. The leathery leaves which have only a few stomata located on the lower surface of the leaf at the base of small depressions help reduce transpiration. The extensive root system enables the tree to use the moisture contained in a large volume of soil. High internal osmotic pressure allows it to extract water from very low moisture soils of 1.5 MPa. These morphological aspects of the plant are complemented by cultivation conditions which favour the formation of rainfall reserves and restrict losses through evaporation. The drawback of the olive tree's ability to adapt to adverse conditions is that the tree reacts by inhibiting its development and reducing shoot and bud formation, as well as production, in the event of prolonged stress and in proportion to the state of the water reserves.

Adequate supplies of water are essential for dissolving mineral salts and water plays an active role in photosynthesis and in the physiology of the plant in general. When there is ample rainfall, the olive tree vegetates better and grows more because the periods of water deficit are shorter. A clear, positive link has been established between natural rainfall from September to May and the ensuing crop. (Ortega Nieto, quoted by Aguilar et al., 1984). See Table 2.

The bibliography contains many references to the benefits of irrigation on olive tree vegetation and production (Romano 1967; Anagnostopoulos 1930; Lakhoua 1976; Samish and Spieguel 1966). Other authors analyse the connection between watering and alternate bearing (Ben Mechlia and Hamrouni 1978; Psyllakis 1975).

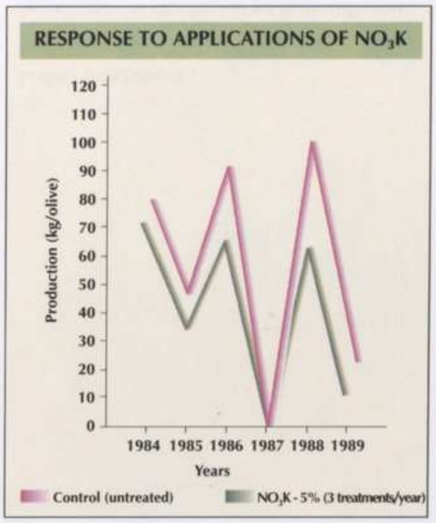


FIGURE 22. Response in the olive to three annual leaf applications of 5% potassium nitrate in a test carried out in Cabra (Córdoba) in a traditional dry-farmed adult olive orchard with cv. Picual in limey soil and with trees showing visible signs of K deficiency checked by leaf analysis (Hermoso and Morales, personal communication). For the 6 years of the test, leaf applications of K raised production by 23%, although the rise was only apparent in the third year of treatment.

TABLE 2
CORRELATION BETWEEN OLIVE PRODUCTION AND RAINFALL
Period 1937-1949. Cv Picual

Years	Production (kg/olive)	Rainfall during previous Oct. - May (mm)
1937-1938	82.16	749
1938-1939	11.66	407
1939-1940	13.83	325
1940-1941	63.33	574
1941-1942	63.00	935
1942-1943	15.83	426
1943-1944	24.66	423
1944-1945	16.41	414
1945-1946	0.00	205
1946-1947	84.16	577
1947-1948	58.33	857
1948-1949	56.33	656
1949-1950	3.00	255
AVERAGE	37.90	520

The correlation coefficient is $r = 0.82$.

The line for regression linking production and rainfall is: $y = 19.51 + 0.11\,x$

y = Expected production (Kg x Olive)

x = Rainfall (mm) collected between 31 October and 31 May previous to harvesting

Soils with good retention capacity. Average ETP = 950 mm/year.

Source: Ortega Nieto (Taken from Aguilar) et al. 1984.

THE WATER, SOIL AND PLANT RELATIONSHIP

Some of the rain falling on the ground and part of the irrigation water go over the ground without seeping in; this is known as run-off. The remainder penetrates into the soil. Gravitational water temporarily fills the spaces oc-

Drip system used for olive orchard irrigation.

cupied by air after heavy rain or irrigation and, within one to three days, as a result of gravity, it is lost as it filters into the deep layers of soil, as long as it can drain through freely.

The water available for the plants is the difference between the Field Capacity and the Permanent Wilting Point (Trocmé and Gras, 1966). It should not be exhausted through irrigation, and only the Easily Usable Reserve should be used, which is estimated at between one- and two-thirds of the Field Capacity. In arid or semi-arid climates and strong soils, no more than 40% should be used.

Water passes from the soil into the atmosphere through the plants, on gradients of decreasing hydric potential. The Hydric Potential at each point is made up of a series of sums:

$$F = Fp + Fo + Fm + Fg$$

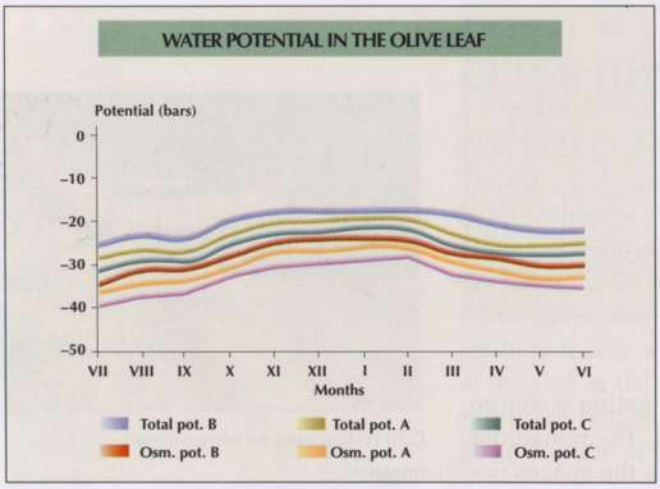
Fp is the pressure or turgidity potential. Fo is the osmotic potential which causes the water to be attracted by the ions of the solutes. Fm is the matrix potential caused by the loss of activity on the colloid surface. Fg is the gravitational potential. Within the plant, this formula can be reduced to $F = Fp + Fo$. The total hydric potential is negative. Trends in the Olive Hydric Potential under different watering schemes are shown in Figure 23 (Laouar, 1978).

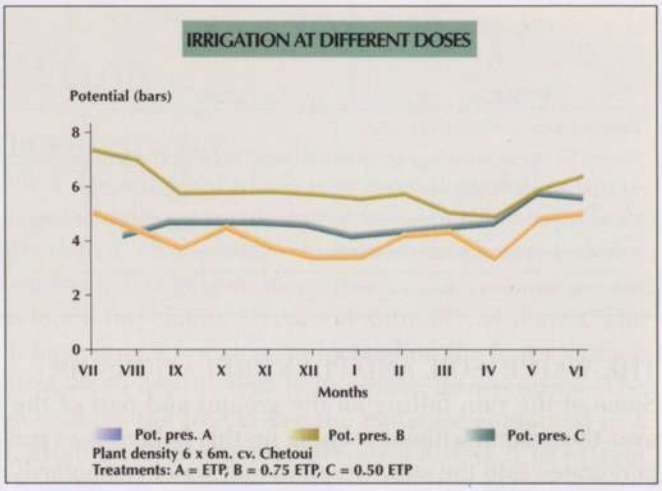
Most of the water absorbed by the plant is lost in the form of vapour during transpiration. Only a small amount is retained for growth, while another much smaller amount is destroyed in photosynthesis and an even smaller amount reacts in the metabolic processes.

Transpiration takes place through the leaf stomata, although it also occurs to a lesser extent through the cuticle. It acts as the plant's cooling mechanism. Since transpiration is limited in xerophytic plants, they are able to tolerate high interior temperatures (40° to 50°C). The mineral nutrients, which are taken in from the soil in a very diluted form are conducted upwards and distributed through the xylem, from soil level to the leaves.

Lack of moisture in the soil causes the hydric potential to drop, and there is a reduction in photosynthetic activity and cellular growth which is reflected in the quantity and quality of the crop. Olive trees behave better when water is short than when waterlogged. They can reduce consumption by about 35% of ETP while maintaining an acceptable physiological condition (Vernet et al., 1964).

FIGURE 23. The lower the water dosage, the lower the Water Potential. Higher doses give F values lower than the average which means that there is an excess of water. This is confirmed by a lower yield of olives (El Amami 1975). The pressure potential which is the difference between total and osmotic potentials is relatively constant in winter and increases during periods of activity; higher values correspond to lower doses. An increase in pressure potential and a simultaneous drop in osmotic potential show that high transpiration accumulates soluble substances or reinforces cell membranes. These variations in pressure potential represent a drought resistance factor (Sánchez Díaz and Kramer, 1983).





Plant density 6 x 6m. cv. Chetoui
Treatments: A = ETP, B = 0.75 ETP, C = 0.50 ETP

Water filtering equipment for drip irrigation. Both sand and mesh filters are used to ensure proper functioning.

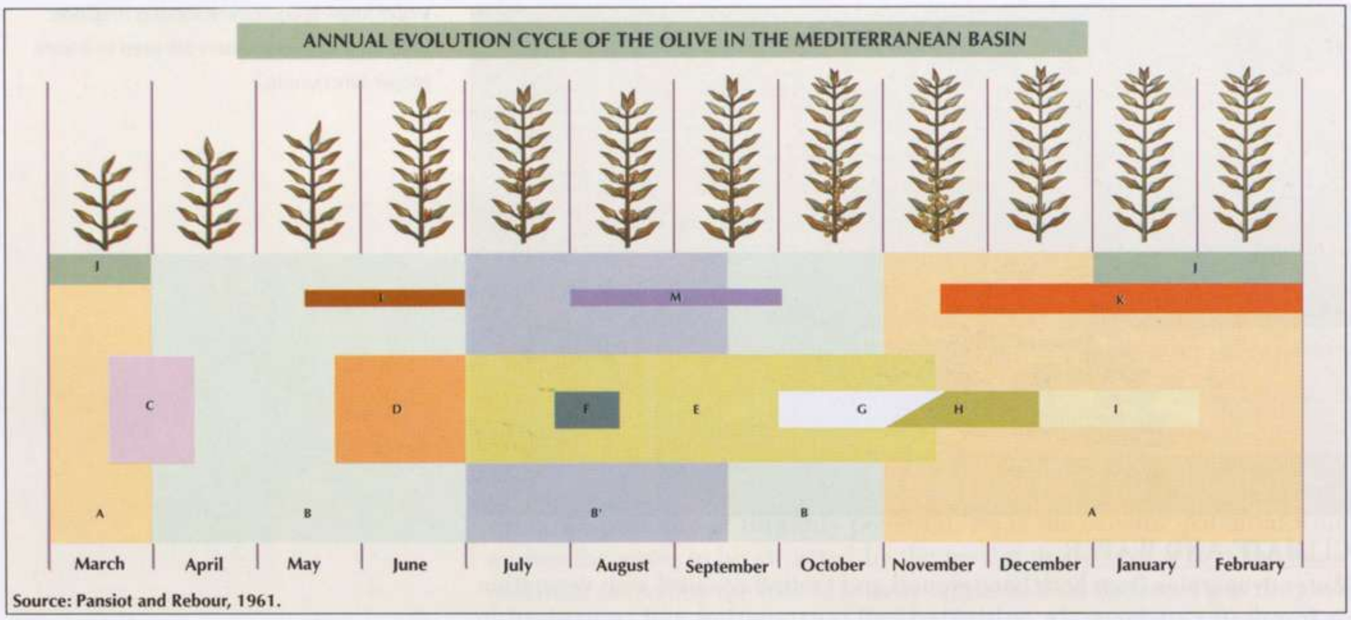
CLIMATE AND WATER

Water evaporates from both bare ground and ground covered with vegetation or free water surfaces. In cultivated soil, evaporation and transpiration occur simultaneously in the plants. The combination of both effects, which are difficult to determine individually, is known as Evapotranspiration (ET). ET requires a source of energy – solar radiation – acting on the plants, the soil and the air surrounding them.

Among the methods used to determine the ET, some consist of measuring the Evaporation (Eo) from a surface of water subjected to weather effects in which there is an unlimited supply of moisture to the atmosphere. The class A evaporimetric tank is often used. Evaporation from very moist ground and from a reservoir is proportional (ET = k Eo) but, as water loss from land increases, it becomes progressively more difficult for the water vapour to pass into the atmosphere. ET measurements therefore differ depending on the moisture content of the soil, its characteristics and the cultivation methods used.

The Evapotranspiration Potential (ETP) concept is generally used, and consists of the evapotranspiration from a surface covered with meadow-type vegetation, in active growth and with a sufficiently moist soil (at Field Capacity) which is not limited by anything other than local weather conditions. In cultivated land, vegetation and humidity conditions do not usually tally with ETP because the soil is partially covered and cultivation is not uniform, etc. ET is therefore different to ETP, but the two are linked by the cultivation coefficient: Kc = ET/ETP. The cultivation coefficient varies throughout the cycle and increases as the plant develops, the foliar area grows and with plant actinty until it comes near to Kc = 1. It then decreases during the ripening stage. The estimate of the amount of water required for the crop is based on the ETP measurement, under standard conditions, and the adjustment coefficients are determined by experimentation (Thornthwite, 1955; Blaney and Criddle, 1962; Turc, 1961; Penman, 1949).

The maximum amount of water that can be stored is calculated according to soil type and root depth. In the rainy season if these (P) exceed ET, the reserve forms up to the useful water limit. When there is a surplus of water, it is lost through percolation. However if ET is greater than P, the reserve drops as the plant takes up water. It is useful to know the average moisture balance of the region and ETP and rainfall can help to determine this, al-



Source: Pansiot and Rebour, 1961.

FIGURE 24. Annual evolution cycle of the olive in the Mediterranean basin

A. Rest period
B. Period of vegetative activity
B'. Period of retarded vegetative actiity.
C. Bud differentiation
D. Flowering - fruit set
E. Fruit growth
F. Hardening of stone
G. Colour change
H. Maturation
I. Vernalisation
J. Pruning
H. Harvesting
L. Critical period (nitrogen assimilation)
M. Critical period (water absorption)

though the balance will be more accurate if estimates are based on the ET and useful rainfall. (Doorembos and Pruitt, 1977; Doorembos and Kassam, 1979).

CRITICAL STAGES IN THE OLIVE TREE CYCLE FOR WATER AVAILABILITY

Figure 24 shows the olive tree's vegetative cycle chart and gives the phenological conditions with the dates when they occur on a 38º-40º N latitude (Pansiot and Rebour, 1961).

The ground accumulates a water reserve during autumn and winter ready for when the shoots appear and the branches grow. The formation of inflorescences and flowering in April and May may occur when there are low water supplies in dry years. Fruit set in June sometimes coincides with water shortage and this is usual when the pit is hardening since, although water may be available, the matrix potentials will be very high. On hot days, transpiration exceeds the speed of absorption of the roots and the olive tree may suffer from water stress. During fruit set and pit hardening, a considerable number of fruits drop to the ground, and one of the causes of this is the physiological adjustment of the tree to its water and nutritional conditions.

In mid-summer, after these periods have passed, olives may postpone their vegetative activity. If the ground is moist in autumn, the branches grow and may give a better crop the following year. In oil olives, the oil formation processes are at their most intense in October and November and, with sufficient moisture, both the quantity and quality of the oil will improve. Autumn rains can provide the moisture required, but if they are late or insufficient, irrigation may be used as an alternative and will bring major benefits to the orchards where it is installed.

OLIVE WATER REQUIREMENTS. WATER CONSUMPTION

One of the aims of the Experimental Field Trials in olive oil producing countries has been to determine the water requirements of the olive by indirect methods. The different cultivars, the weather conditions of the region and weather conditions during the trial period, the soil type, age of the olives, ground surface covered or type of orchard all give different results.

Lysimetric methods

Lysimetric experiments on olives carried out in Tunisia and Corsica have led to the conclusion that densely planted orchards with adequate moisture use up to 70% of the ETP (Le Bourdellés, 1980).

In Cordoba (Spain), trials were performed on olives grown in containers to determine transpiration in young olives from June to August, with a moist soil to Field Capacity (Cruz Conde and Fuentes, 1984). These trials demonstrated that there is a link between water requirements and the shaded ground surface (See Table 3). The application of the results obtained gives maximum yields, as shown in Table 4.

TABLE 3
WATER LOSS THROUGH TRANSPIRATION
Well-developed olives in Cordoba, Spain. cv. Picual

No. olives per ha	Cover	Max. daily transpiration (l/olive)	Daily dose mm.	T/ETP Kc
100	25	135	1.35	0.25
150	36	103	1.53	0.29
200	40	85	1.70	0.32
250	43	73	1.82	0.34
300	45	65	1.95	0.36
400	50	54	2.16	0.40

Mean daily transpiration in young olives, June/August, 0.35 l/m^2 of leaf with evaporation from Tank A of 6.6 mm and ETP (Thornthwite) of 5.37 mm.

ETP April/October, 820 mm.

Source: Data by Cruz-Conde and Fuentes, 1984.

Methods based on soil moisture measurements

Le Bourdellés et al. (1983) measured water consumption in Corsica over three crop years in cv Picholine using drip and sprinkler irrigation. The total amount of water used in the drip system varied between 0.50 ETP and 0.73 ETP and gave results of between 340mm and 374mm per irrigation period. In sprinkler irrigation, consumption of between 0.38 and 0.44 ETP was measured per watering season.

In Crete, Michelakis et al. (1988), Table 5, used basin irrigation and various combinations of trickle irrigation. Less water was used in basin irrigation than in the trickle system, and irrigation at 15 bars used less water than 0.2 bars. In the sixth year, the size of the canopy, the height of the tree and the diameter of the trunk were the same for the different treatments, and considerably higher than in the unirrigated control trees. This demonstrated that olives benefit from watering and are able to extract it at tensions close to the Permanent Wilting Point (PWP).

Methods based on the olive's response to irrigation dosages

A large number of tests have been carried out using a system which compares water supplies with ETP or with tank evaporation.

In Sardinia, Aggabio (1983), quoted by Dettori (1987), worked on the hypothesis that olive ET was equivalent to 42% of evaporation in the Class A

TABLE 4
PRODUCTION ACCORDING TO DRIP IRRIGATION DOSAGE
Plant density 6 x 6m. 1976. cv. Picual. Cordoba (Spain). Average production from 1980 to 1983

Treatment	Olive production Kg/ha	Average dose mm.
1.33 A	3,523	112
A	3,726	84
0.67 A	3,078	56
0.33 A	2,756	28
No irrigation	2,419	0

Treatment A is equivalent to transpiration measured experimentally in pots.

ETP April /October, 820 mm.

Source: Data by Cruz-Conde and Fuentes, 1984.

tank. He applied this dosage as well as 60% and 30% of the ET and compared the results with those of an unirrigated control. The results are given in Table 6.

The Leaf Water Potential indicated that 100% ET dosage was rather low once the pit had hardened.

TABLE 5
VOLUMES OF WATER APPLIED IN VARIOUS IRRIGATION TREATMENTS
Plant density 5 x 5m. 1979. Cv. Kalamon. Crete (Greece)

Potential soil water (bars)	Irrigation system	Years 3-5 mm	Years 3-5 %	Year 6 mm	Year 6 %
F = 0.2	Basins	111	92	247	56
F = 0.2	Drip	121	100	444	100
F = 15	Basins	62	51	187	42
F = 15	Drip	81	67	323	72

The basins measure 2 m in diameter.

In the sixth year, canopy size, tree height and trunk diameter gave similar values for all the treatments. They were much higher than those in the control without irrigation.

Source: Michelakis and Vougiucalou, 1988.

TABLE 6
INFLUENCE OF IRRIGATION DOSAGE ON PRODUCTION AND FRUITS
Plant density 4 x 4m. Age 10 years. Cv. Ascolana tenera. Sprinkling.

Irrigation volume	Production t/ha	Olive Weight g	Mesocarp size mm	Stone size mm	Ratio mesocarp/ stone
0,42 E	6.8 d	6.6 c	13.3 c	7.6 b	1.8 b
0,25 E	5.7 c	6.5 c	12.6 c	7.1 b	1.8 b
0,13 E	3.3 b	5.1 b	11.5 b	6.6 a	1.7 a
Control	1.5 a	4.5 a	10.0 a	5.9 a	1.7 a

E = average evaporation in Class A Tank

The values followed by different letters show a statistically significant difference of 5%.

Source: Aggabio 1983, quoted by Dettori 1987.

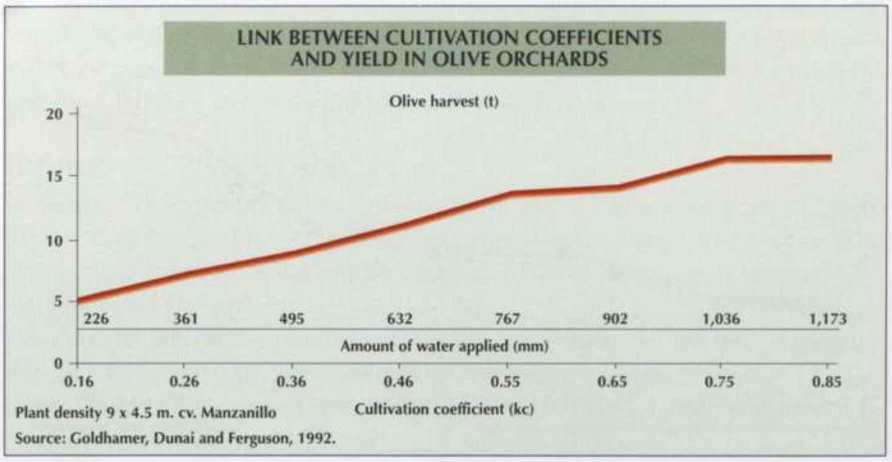
TABLE 7
RESPONSE IN OLIVE ORCHARDS TO IRRIGATION
Plant density 4 x 4m. Age 10. cv. Ascolana tenera. 1982-84

Treatment	Annual average water dose m^3/ha	Annual average production t/ha	Annual trunk growth %	Average fruit weight g
0,60 E	3,929	6.1 C	17.6 C	6,6 C
0,50 E	3,271	6.2 C	17.4 C	6,4 C
0,40 E	2,617	5.3 B	13.4 B	6,1 B
Non-irrigated	0	3.8 A	10.4 A	4,2 A

E = Evaporimeter reading, Class A Tank

The values followed by different letters show statistically significant differences (1%).

Source: Dettori 1987.



Plant density 9 x 4.5 m. cv. Manzanillo
Source: Goldhamer, Dunai and Ferguson, 1992.

FIGURE 25. There is a first stage in response up to Kc = 0.55 in which production shows a clear increase in line with the increase in water provision. In the second stretch, for Kc values between 0.55 and 0.75, the response is lower. From Kc = 0.75, there is no increase in yield.

In another test in Sardinia carried out by Dettori (1987), 60%, 50% and 40% supplies of ETP were given in comparison with an unirrigated control, and the results are shown in Table 7. The 50% ETP dosage gave the same yield, trunk growth and fruit weight as the 60% ETP dosage.

In California, Goldhamer, Dunai and Ferguson (1993) applied eight irrigation dosages ranging from 0.16 to 0.85 ETP (calculated on the basis of a modified Penman equation) over two irrigation periods on adult olives. For the 0.75 cultivation coefficient, the olives did not suffer from water stress, as is demonstrated in the measurements of leaf water potential which remained constant and in the region of - 0.5 PMa. The crops increased as a result of the water supplies, as shown in Figure 25.

In Cordoba (Spain), the Humet company (1981) carried out a test applying daily dosages equivalent to 0.5, 1, 2, 3 and 4mm compared with an unirrigated control. The olive yield increased with the dosage of water, but oil production remained the same at dosages of 3 and 4mm/day (see Table 8).

Discontinuous application of water as relief irrigation

The positive response of olive orchards in years of high rainfall has traditionally, particularly in regions with scant rainfall, pointed towards the benefits of supplementing soil reserves with irrigation when water is available.

TABLE 8
DRIP IRRIGATION DOSAGE. OLIVE ORCHARD YIELD
Plant density 8 x 4 m in 1970. Cv. Picual. Data from 1981

Treatments		Irrigation water	ETP irrigation	Yield Kg/olive	
mm/day	l/olive/day	m^3/olive	ratio	Olives	Oil
0	0	0	0	18.46	3.06
0.5	16	2.28	0,11	20.13	3.08
1	32	4.03	0,20	23.51	4.00
2	64	7.85	0,39	26.54	3.80
3	96	11.24	0,55	29.05	4.48
4	128	13.8	0,68	36.60	4.54

Source: Humet Riegos, 1981.

This means watering during seasons other than those when the plant's requirements are greatest, mainly in winter and spring and, less frequently, in autumn.

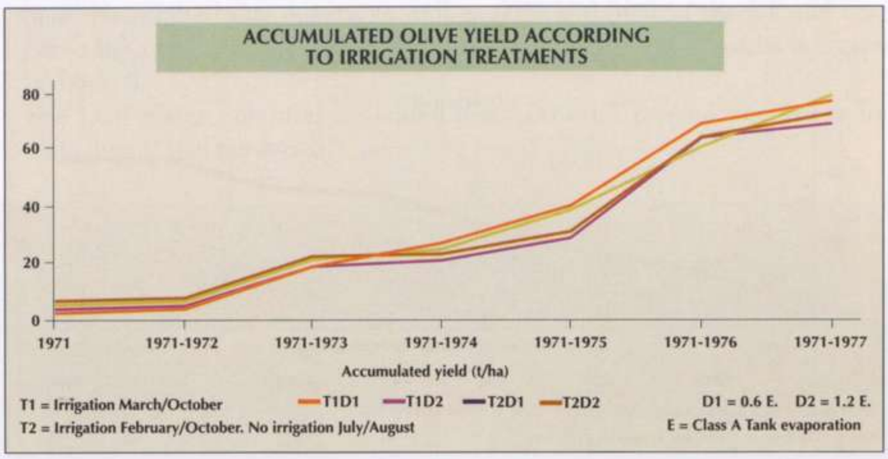


FIGURE 26. Accumulated olive yield according to irrigation treatments.

The effect of such irrigation has been studied on traditional orchards at the Olive Orchard Field Station in Jaen and the results are shown on Table 9. All the trees irrigated gave increased yields ranging from 40% to 70%. Autumn irrigation improved olive production and increased the proportion of oil; the effects were seen in the swelling of the fruits and in branch growth, particularly during dry autumns.

In the central region of Tunisia, the effect of irrigation with salt water from March to October was compared with other orchards where irrigation was stopped during July and August. No differences in yields were appreciable (see Figure 26).

RECOMMENDATIONS FOR IRRIGATION

All the tests demonstrated that olives respond well to irrigation compared with unirrigated control trees, even when very low dosages are applied or when supplies are sporadic and given outside the dry period.

If water is available throughout the whole crop cycle, the rational answer is to provide as much water as is needed to compensate for the shortage. In general terms, irrigation should cover the period from April to October, and be adapted depending on the year and the region.

In highly-efficient irrigation systems such as localized watering and particularly in drip systems in shaded areas, the best vegetative and productive response was achieved by applying between 45% and 65% of the ETP, after evaluating the useful rainfall during the irrigation period. A cultivation coefficient of 0.50 is recommended and has given excellent results in most cases. When the olives are well-spaced or small in size, and the surface covered by the crop is less than 45%, the Kc could be adjusted by applying a reduction factor (0.7 for 25% coverage, 0.75 for 30%, 0.80 for 35% and 0.90 for 40%). The monthly variation in crop coefficient is very low, according to the results shown by Dettori (1987), applying the FAO methods (Doorembos and Pruit, 1977) to Sardinian olive orchards, with an interval of between 0.5 and 0.6 for Kc, with lowest results in summer.

When using systems with less hydraulic efficiency than drip irrigation (sprinklers, canals, basins, etc.), the volumes to be applied should take into consideration losses through evaporation and infiltration into deep soil layers. Relief irrigation for olive orchards when water resources are very limited has also been successful. Water should be applied until Field Capacity is reached in the root area and be continued until late spring. Autumn irrigation helps the crop mature, and it is often sufficient to water in September

TABLE 9
PRODUCTION RESPONSE IN THE OLIVE TO ADDITIONAL IRRIGATION. Plant density 12 x 12 m. Adult olive orchard. cv. Picual

Treatments	Average yield (1974-1984) Kg/ha	
	Olives	Oil
T. Non irrigated	1,827	351
A. 100 mm (1 irrigation: Winter)	2,576	534
B. 200 mm (2 irrigations: Winter. Spring)	2,569	511
C. 200 mm (2 irrigations: Winter. Autumn)	3,031	697
D. 300 mm (3 irrigations: Winter. Spring. Autumn)	3,241	715

Useful soil reserves, 200 mm. Basin irrigation.
Average annual ETP, 950 mm.

Source: Estación de Olivicultura de Jaén, 1985.

(green table olives) or in October, prior to the autumn rains. Relief irrigation should be done over the largest possible area of ground to achieve maximum water storage. It is essential to know the Field Capacity and to monitor the moisture balance in the soil to rationalise such irrigation.

IRRIGATION WATER QUALITY

In many olive-growing areas, although the water has a very high salt content, it may be used for irrigation if appropriate precautions are taken. The problems it may cause should be considered from the point of view of both the plant and the soil.

The tension which the plant has to overcome in order to extract water from the soil when salts are incorporated in the irrigation water is Fm + Fo. The use of saline water amounts to raising the soil water tension, which makes extraction more difficult. The salt will not accumulate in the ground if it is leached out by rain and there is an efficient drainage system. Water with moderate salinity can be used as long as there is drainage, the flow is higher than that of fresh water and the crop resists these adverse conditions. The amount of salts entering the ground through the irrigation system should leave through the drainage system.

The quality of water is determined mainly by the following factors: the quantity of soluble salts, the sodium concentration compared with the calcium and magnesium concentration and the concentration of bicarbonates in relation to the calcium and magnesium and boron concentration. The parameters most frequently used to classify irrigation water are: Electrical Conductivity (EC), closely linked to the total amount of salts, and the Sodium Absorption Relationship (SAR). The US Soil Salinity Laboratory has established the irrigation water classification given in Figure 27.

Olives are considered to tolerate salinity well although there are differences depending on the variety. In a saline medium, olive growth and productivity decline. The tree tolerates concentrations of boron ranging from 1 to 2 ppm. In Tunisia (Bouaziz, 1989), irrigation water with EC = 4.9 ds/m and SAR = 7.5 classified at the limit of groups C4-S2 and C4-S3 was used producing a slightly depressive effect on olive production and salinisation of the soil which settled within acceptable limits (see Figure 26).

Pruning should always aim for a high leaf/wood ratio. Above: fork-shaped tree with sparse foliage and aged scaffold branches. Below: trees over one hundred years old with a high leaf/wood ratio that, for tens of years, have been receiving the rejuvenation pruning that is typical of the Jaén area of Spain.

FERTIRRIGATION

The application of fertilisers with localized irrigation is known as fertirrigation. Localisation at the watering points improves the efficiency of the fertiliser, and it may be sufficient to apply between a third and half the fertilizing units, compared with traditional methods.

In order to schedule fertirrigation, the trees' needs have to be determined in terms of extraction by the crops, nutritional status, which can be analysed by leaf diagnosis, and the periods when requirements for each of the nutrients are greatest. This will give the number of fertilizing elements to be supplied which, in conjunction with the water dosage established for irrigation, enables evaluation of the concentrations (g/m3) to be applied in each period. As an example, Le Bourdellés (1977) in Corsica established fertilisation with a fertilising compound at a concentration of 25 - 5 - 16 at a rate of 40 Kg/ha during each of the 25 weeks from March to August. The total supply is 1000 Kg/ha of fertiliser with 250 - 50 - 160 Kg/ha of fertilising principles. In Andalusia, on an orchard with 200 olives per hectare, a total supply of 150 - 80 - 100 Kg/ha of N, $P_2 0_5$ and $K_2 0$ respectively is recommended.

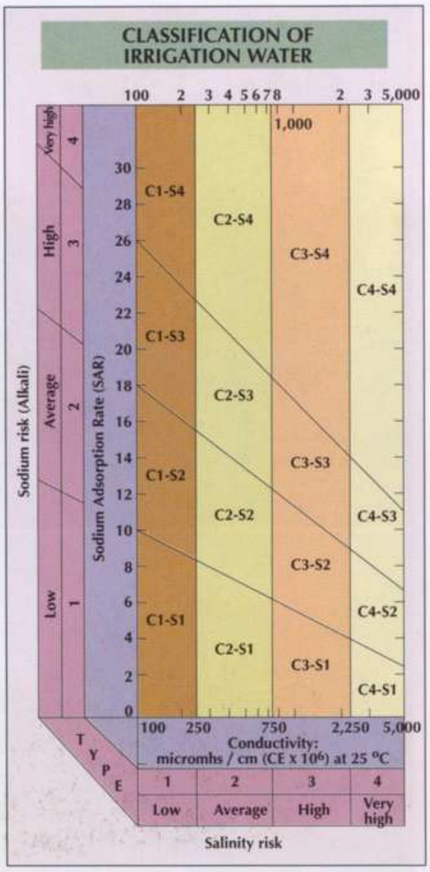


FIGURE 27. Classification of irrigation water.

OLIVE TREE TRAINING AND PRUNING METHODS

GENERAL PRINCIPLES OF OLIVE TREE PRUNING

Pruning consists of a series of operations performed on trees to modify their natural form of vegetation by encouraging or restricting branch development, in order to adapt the tree shape to the productive environment achieving maximum productivity.

Pruning is necessary for maintaining the equilibrium between the vegetative and reproductive functions, making the tree's maximum production compatible with its vitality, shortening its non-productive period during youth, lengthening its productive period to a maximum and delaying decadence, ageing and death.

Pruning has to be adapted to the different phases in the tree's life. During the non-productive period, low intensity pruning should be performed. During the adult period, light pruning is required and, when ageing begins, the olive has to be rejuvenated by heavy pruning spread over certain time intervals to allow recovery.

Maintaining excessively compact and spherical-shaped canopies prevents proper utilisation of light, and for a specific canopy volume these shapes lead to minimum fruiting. On the other hand, when pruning makes the branches spread out almost horizontally, the excess light makes the olive react and continuously put out vigorous suckers, wasting sap and reducing production. Pruning operations throughout the olive's life span should balance growth and fruiting, should not devitalise or prematurely age the tree, should be economic and should bear in mind that the main constraint on productivity is water.

In order to determine pruning intensity and to decide whether or not to prune in a particular year, the following should be analysed: a) rainfall during the autumn-winter period immediately prior to pruning, b) the previous year's harvest, c) the vegetative condition of the trees at the time of pruning, d) the purpose of the crop (table olives or oil olives), and e) the planting pattern and tree development.

When water resources are low (Figure 28), the type of pruning performed may have a minor effect on production (Ferreira, 1979; Solé and Florensa, 1991), as long as it does not affect the anatomy and physiology of the tree.

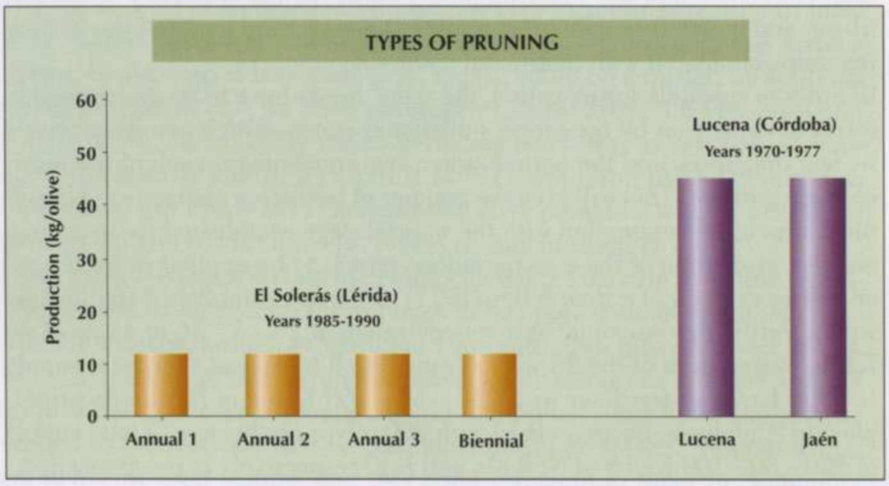


FIGURE 28. In dry-farming conditions in which water is the main limiting factor for production, the type of pruning carried out may have little effect on yield in the long term. This is the case in the two tests shown on production pruning (Source: Ferreira, 1979; Solé and Florensa, 1991).

FIGURE 29. In olive orchards growing in good areas for production, with good average rainfall and wide planting densities, it may be advisable to lengthen the time between consecutive pruning. The graph shows average yield in three long-duration tests carried out in traditional olive orchards in Cabra (Córdoba), Cazorla (Jaén) and Mengíbar (Jaén). Traditional biennial pruning gave lower average yields than pruning carried out every 3 or 4 years.

On no account should the canopy size be reduced excessively by heavy pruning in the event of several years' drought, since the progressive reduction in volume may lead to a permanent reduction in the orchard's productive potential, as when there is sufficient or abundant rainfall, average production levels only increase with large crop yields.

Olive pruning is usually performed after harvesting and, in traditional olive-growing regions, it is carried out from January to April although, in areas where frosts are common, pruning should be avoided during the winter months.

Biennial pruning is very common for olives, although in olives for oil and table olives with widely-spaced planting densities, the benefits of this system have not been proved. Testing in Andalusia (Figure 29) on fertile ground with adequate rainfall, and on olive trees which are not overladen with wood, has shown that in some cases longer cycles, possibly triennial cycles, give better results, particularly for oil olives.

Alternate bearing may be caused by the olive's tendency to produce more fruit than it can feed. This prevents the normal growth of shoots bearing the next crop and leads to nutritional deficiencies in the trees after harvesting. In years when an excessively high yield is forecast, pruning should aim at cutting down the number of flower buds by thinning out fruit-bearing branches.

TRAINING

The purpose of training is to build a framework compatible with the planting pattern selected that will sustain the plant organs and the crops produced during the tree's bearing lifetime. The possibility of using full-scale machine harvesting depends on whether suitable frameworks have been built up.

Training must respect the natural tendency of the species and of the variety in question. Morettini (1972) demonstrated that free shapes work best in olive orchards because forced shaping delays initial bearing and reduces the trees' productive potential. In addition, it calls for severe, meticulous and costly pruning, involving a lot of skilled labour.

Training in traditional orchards

Training methods in traditional orchards are well-known by olive growers and have been perfectly described in the literature (Roventini, 1936; Pansiot and Rebour, 1961; Cadahia Cicuendez, 1972; Morettini, 1972; Loussert

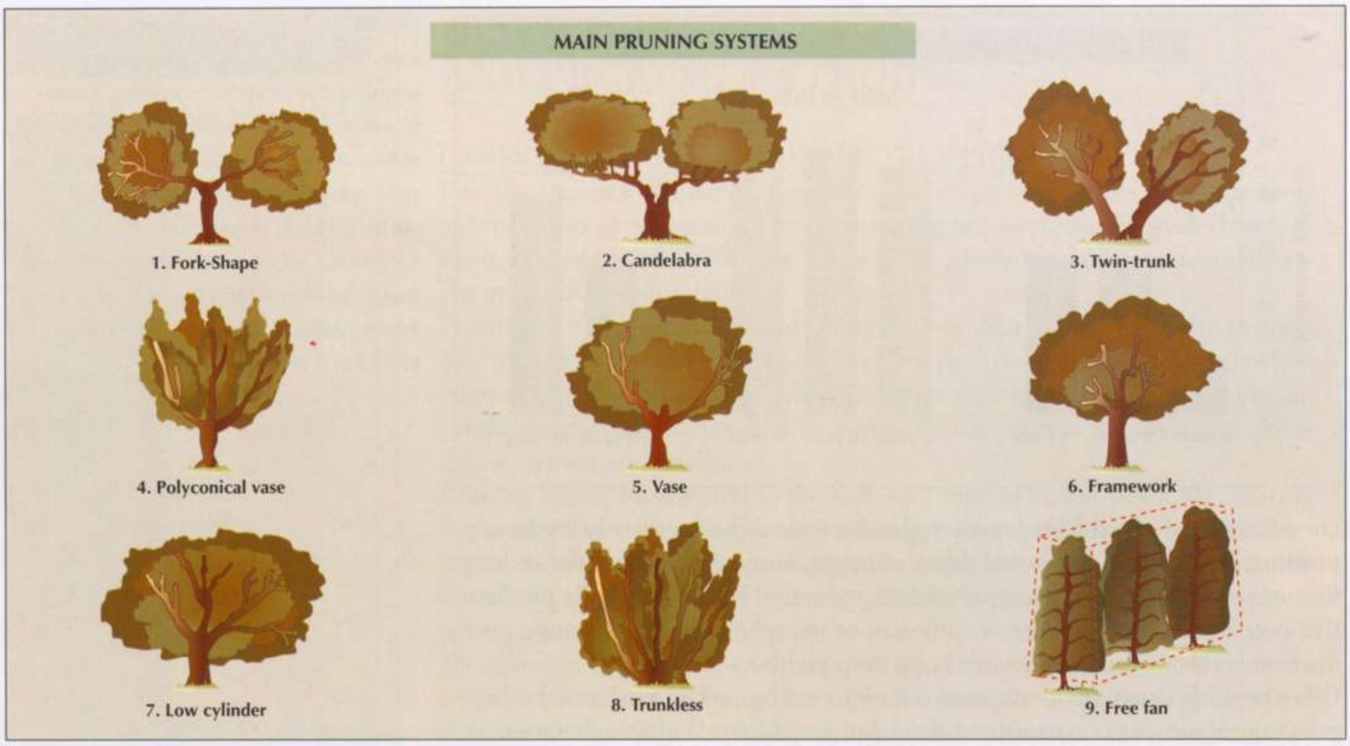


FIGURE 30. Main pruning systems used in olive cultivation in the different olive-growing areas (Pansiot and Rebour, 1961). 1: Training with one trunk and two scaffold branches - system applied in the Seville area in table olive orchards. 2: Candelabra pruning used in several Mediterranean areas including the north of Tunisia. Pruning is carried out from the ground using a tool with a very long handle. 3: Twin-trunk training typical in Andalusia is achieved starting with two leafy stem cuttings planted in the same hole. 4: Polyconical vase shape, very common in Italy. This is the Tonini and Roventini method with each of the scaffold branches forming a cone shape. 5: Vase or round shape (Provence, France), cross-section. 6: Framework formed by dichotomy. 7: Low cylinder shape (Sfax, Tunisia). Note the low fruit-bearing branches. 8: Trunkless pruning, cv. Chetoui, Tunisia, Boglio method. 9: Free fan shape, Italy, proposed by Breviglieri.

and Brousse, 1980; Fontanazza, 1984; Pastor and Humanes, 1989). Figure 30 gives a diagram of the main shapes used in the different olive-growing regions according to Pansiot and Rebour (1961). They recommend the simplest shapes because they adapt best to the trees' natural tendency, enhancing production while not entailing costly pruning. In addition to these training methods is the classical multi-trunk shape predominant in Andalusia and known in Spain as the *estaca* or *garrote* (Ortega Nieto, 1969) and *vaso cespugliato* in Italy (Morettini, 1972).

The objective of this type of training was to achieve maximum canopy size in the shortest possible period. This is very important in the case of orchards with large planting densities but is not applicable in today's intensive olive farming.

Training in intensive orchards

Training methods for densely-spaced orchards are different to those used in traditional olive growing. The goal is to achieve shapes which will take maximum advantage of their environment as early as possible and, in particular, of solar radiation which in densely-spaced adult orchards is often the factor that most seriously restricts production because of the shaded areas.

It is essential to form a single trunk to facilitate the use of shaking machines so that more olives can be picked per time unit.

Single-trunk olive trees give less expanded shapes with a lower canopy volume for the same leaf mass. This is important in dense orchards since it allows light and available space to be put to better use.

The ideal tree shape proposed for new intensive growing methods is achieved from a plant trained with a single trunk in a nursery. There should be not more than 3 main branches at about 100 to 120 cm from the ground and thereafter a dichotomic structure should be formed giving a relatively freely-growing hollow vase shape. The scaffold branches are thus protected from direct sunlight by weak shoots which are maintained for this purpose on the inside of the canopy.

Minimum pruning should be done to achieve this type of tree, and the use of a stake or support during the first three years of life of the new orchard is recommended as this helps keep the terminal bud in a vertical position. During the first few years, low-intensity pruning may be carried out at intervals during the growing season, in order to gradually give the tree the desired shape without upsetting the leaf-root relationship.

This is not the only possible tree shape. In Italy, Fontanazza (1984) suggested the monoconical shape, a free form with the branches arranged in helicoidal fashion around a single central axis. This model is also achieved with minimum pruning. The objective of this type of training is to increase the efficiency of trunk shakers, although it has not yet been proved successful in practice (Prioetti et al., 1991).

PRUNING TO PROMOTE FRUIT PRODUCTION

After the trees are fully formed, and when this has been done correctly, minimum pruning only is required, particularly in irrigated orchards and dry orchards with good levels of rainfall. During this period, well-cultivated olives maintain a high leaf/wood ratio and pruning will aim at improving lighting within the canopy. This improves the quantity and quality of the fruit yield and also helps harvesting.

Pruners should try to ensure that the branches are kept shaded, that as many leaves as possible are conserved and that they are well lit. Direct sunlight on the trunk and main branches will cause burning and premature ageing, reducing the productive life of the orchard.

It is important to ensure that the size of the olive trees does not exceed the optimum productive canopy volume per hectare which the orchard environment is capable of maintaining. Excessive volume will have a negative effect on the quality, regularity and quantity of production, as a result of deficient lighting and excessive and rapid consumption of water from the soil (Figure 31). In summer, when fruit development is at a critical stage, excess

When a tree becomes old, the practice of removing certain branches may help to rejuvenate the canopy, so that centenarian trees can still have a canopy similar to that of young trees. The photograph shows a renovation pruning cut on a cv. Picual tree and the shoots growing from the adventitious buds present in the old wood. These shoots will replace the branches that have been removed.

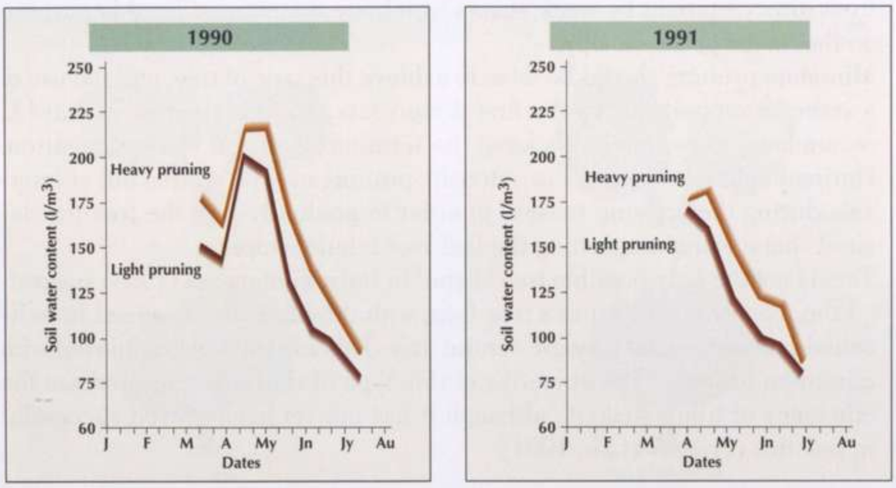


FIGURE 31. Soil water content (0-80 cm) during the spring to summer period in 1990 and 1991 in two olive orchards, one with heary pruning (canopy volume 8,000 m^3/ha) and the other with light pruning (10,500 m^3/ha). The trees that were less severely pruned consumed the soil water faster so less water was available in the summer and this affected fruit growth and the oil formation process.

volume causes water stress problems. This may lead to a low growth rate in the shoots and drupes, and a deficient nutritional status of the trees. In extreme cases, there may be massive fruit fall. Figure 31 shows how severely pruned olives, with a canopy volume of 8,000 m^3/ha, consumed water from the soil more slowly than lightly pruned olives, which were allowed to reach a volume of 10,500 m^3/ha. In the latter, which had access to less water throughout the summer, the reduction in fruit size and oil content had a negative effect on the ripening of the olives. It is therefore necessary to monitor tree size, and to seek a balance when pruning between growth and fruit-bearing. Planting density plays a major role, since in high-density orchards there are more problems of competition between plants.

REJUVENATION AND REGENERATION PRUNING

In olive trees, as in all living beings, there is a slow decay throughout the life of the tree and, at the end of the adult period, signs of ageing start to appear and the tree becomes less productive.

With age, and sometimes as a result of premature ageing caused by unfavourable environmental conditions, olives start to accumulate wood, even when production pruning has been performed correctly. Average yield falls and alternate bearing is accentuated with a loss of quality in the olives. A low rate of vegetative growth of the new shoots, small leaves of a dull green colour, and even defoliation on some branches, are all indications to the pruner that a branch should be replaced and that he should begin thorough, regular and continuous rejuvation of the canopy.

Olives have a large number of latent buds in the old wood which, when needed and duly stimulated by pruning, develop as wood buds, producing vigorous branches which, in time, are capable of regenerating the tree. The success of rejuvenation pruning in Andalusia, where even hundred-year-old olive orchards are in a good vegetative and productive condition, is a result of the olive tree's capacity for self-regeneration.

In the Mediterranean basin olive orchards, most of the feasible rejuvenation pruning systems are based on two models which are set out in Figures 32 and 33. The first is suitable for relatively young adult olives, which are not fully developed and do not have too much wood. This system is used successfully in the majority of Andalusian olive orchards. The second system (Fontanazza, 1983), shown in Figure 33, is used in a large number of Mediterranean olive-growing areas with highly-developed centenarian olives which have never undergone wood rejuvenation pruning. The height and canopy volume of the trees is out of proportion with the potential of the productive environment. Their very low leaf/wood relationship is the result of pruning small branches in the experiment. When this regeneration system is used, the first pruning operation can prove to be over-severe, but is the only solution for revitalizing this kind of olive orchard. Less heavy pruning is relatively ineffective for achieving the objectives pursued.

Mechanical harvesting can be applied in intensive orchards. The rotating disks of the pruning machine cut the braches in such a way as to maintain the desired canopy volume.

MACHINE PRUNING

Machine pruning is performed with a rotating disk pruning machine installed on a medium-sized tractor which moves along the lanes at a constant speed and performs the work shown in Figure 34, i.e. indiscriminate cuts more or less perpendicular to the ground (Figure 34a), or more or less parallel to the ground (Figure 34b).

In the last 15 years, several medium and long-term experiments have been performed in different types of olive orchard (Pastor et al., 1991) in order to study the feasibility of this pruning method, because the lack of skilled pruners is one of the main problems in olive growing today.

The tests have given very promising results, particularly in irrigated olive orchards. The results of 13-year-long tests in Jaen (Spain) are shown in Figure 35, where average production of machine-pruned olives exceeded the crops of trees which had been manually pruned in the usual local manner. The research performed (Pastor et al., 1991) showed that machine pruning is viable in the following situations: a) in production pruning during the young adult period, as a substitute for manual production pruning; b) in intensive orchards to adapt canopy volume to optimal production and to increase space between trees to make room for machinery while improving aeration and lighting; and c) in heavy thinning, to rejuvenate intensive olive orchards which have aged as a result of high productivity and excessive volume.

Machine pruning should be heavy but should only be performed once every three or four years so that the tree can recover fully and in order for production to benefit from the vegetative growth formed as a result of the cuts made

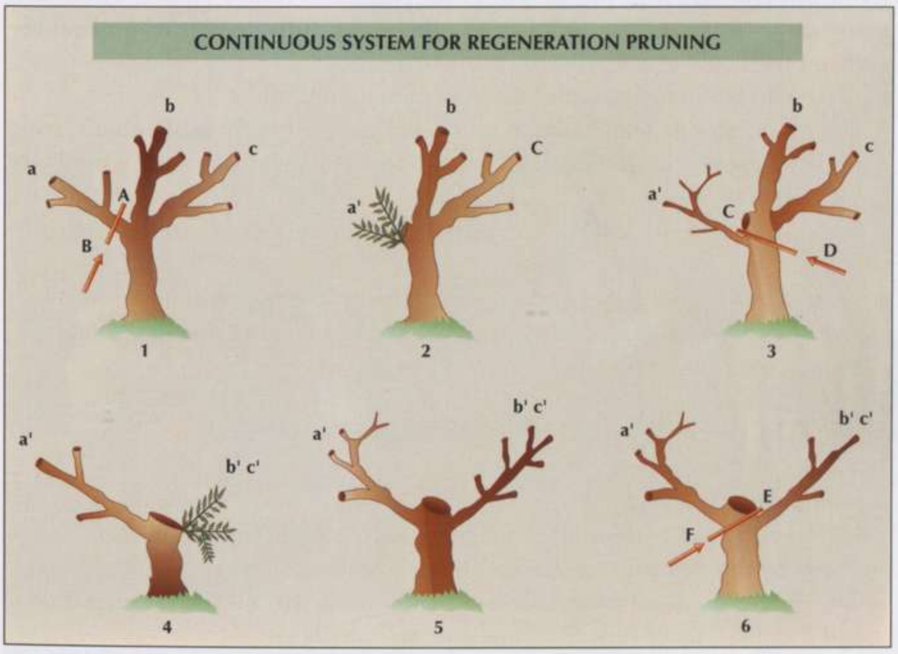


FIGURE 32. Diagram of the continuous system for regeneration pruning used in Andalusian olive orchards. The different phases can be seen after the start of rejuvenation (1), with the amputation of one of the main branches and (2) the shoots formed as a result of the cut, until the tree is completely renovated (5), after several amputations (3) and the resulting shoots (4). The 3-branched tree is left with 2 branches after complete renovation of the canopy. In (6) a new rejuvenation cycle begins which will continue throughout the productive life cycle of this olive orchard (Pastor and Humanes, 1989).

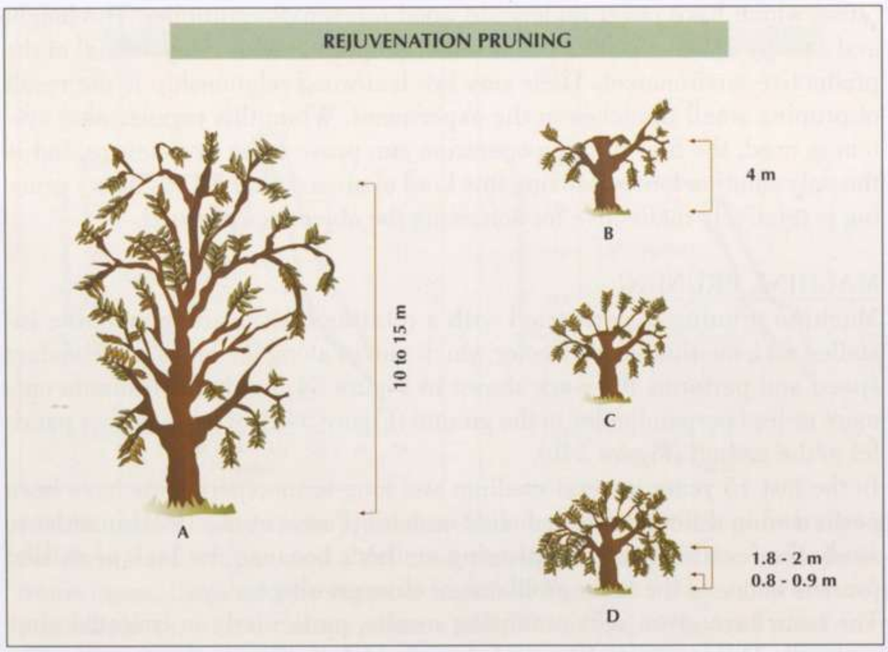


FIGURE 33. Diagram of the different steps taken to rejuvenate a typical olive tree in the warm Mediterranean areas. The tree had a low leaf-wood ratio and an excessively high canopy which made olive harvesting difficult as well as the application of cultural care (A). By means of very severe pruning (B), after a period of 4-5 years, it is possible to obtain rejuvenated trees that are economically viable (D). After 2 or 3 years, it is necessary to select the branches (C) that will form the new scaffold for the rejuvenated tree (Fontanazza, 1983).

by the machine. It is essential to alternate machine pruning with basic manual pruning inside the tree to clear the canopy and avoid the risk of the olive accumulating large quantities of suckers, stumps and dead wood which, unless removed, render it non-productive.

However the system is not viable in adult orchards subjected to rejuvenation because of the low shoot growth capacity of old branches.

HARVESTING

Harvesting is one of the most important olive-growing operations, because the correct choice of how and when to harvest affects the quantity and quality of the annual crop, the cost of production and future yields. There are many aspects to consider and they should be carefully combined for best results on the basis of the following objectives:

- The fruit should contain the maximum amount of oil.
- The oil obtained should be the best possible quality. In table olives, fruit quality depends on the demands of the technological processing methods and particularly on size.
- Olive trees should suffer minimum damage in order to safeguard future crops.
- The overall cost of the operation should be as low as possible.

Sometimes a compromise solution has to be found if the maximum number of objectives is to be reached.

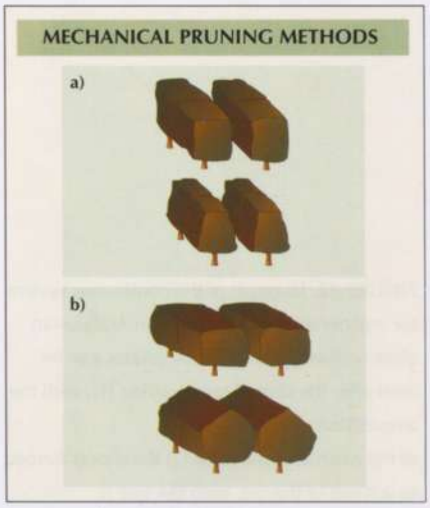


FIGURE 34. Mechanical pruning methods using a disc mower. Cuts on lateral faces of the tree at differing angles (A), or heading back at the top of the crown parallel to the ground, or at an angle to improve light utilisation (B).

HOW TO CHOOSE THE BEST TIME TO HARVEST

Formation of oil

The period when the oil in the fruit reaches its maximum weight can be recognized by the following easily-identifiable factors:

- The external colour of the olives - when there are no more green olives and the majority of the olives are turning colour.

- Skin colour and colour penetrating the olive flesh. Various Maturity Indices have been established on the basis of this criterion, including those devised by the Olive Growing Station in Jaen (Ministry of Agriculture, 1976).
- The relationship between oil weight and the dry matter. This parameter evolves according to the weight of the oil content. Each cultivar has characteristic values which indicate the degree of maturity of the fruit.
- The oil weight in a specific number of olives.

The quality of the oil is related to the composition of the saponifiable fraction, which alters during ripening, and particularly the unsaponifiable fraction, the components of which give maximum or minimum values when there is a predominance of olives turning colour (Fiorino and Nizzi, 1991; Ben Salah et al., 1986; Uceda and Frias, 1985; Montedoro and Garafolo, 1984). The Critical Harvest Time is reached when the green olives have disappeared and most are changing colour (Civantos et al., 1992).

Natural olive fall

Natural fruit drop is a result of maturity. Every cultivar behaves in a different way and weather conditions also affect crops (Fiorino et al., 1975; Civantos, 1983).

Fruit abscission is caused by the formation of a layer which develops as maturity draws near. Artificial methods can be used to enhance the development of this layer using ethylene-releasing chemicals (Alsol, Ethrel, etc.). Abscission products reduce the olive Drop Resistance Threshold (DRT) and cause increased leaf loss. The effect of ethylene on defoliation lasts from one to three months after application and interferes with the differentiation of flower buds, resulting in reduced flowering the following year (Lavee, 1976). As maturity approaches, the DRT falls naturally and there is a clear correlation with increased fruit fall (Ministry of Agriculture, Spain, 1976; Porras, 1987). When the Critical Harvest Time is over, there is more likelihood of

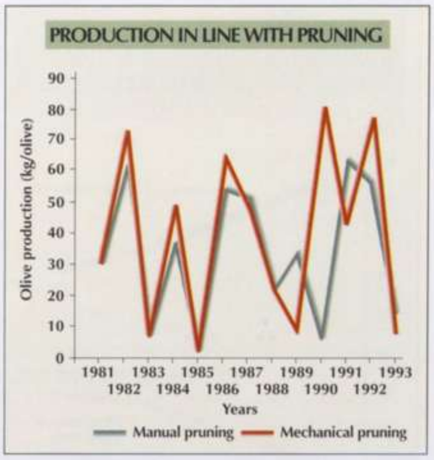
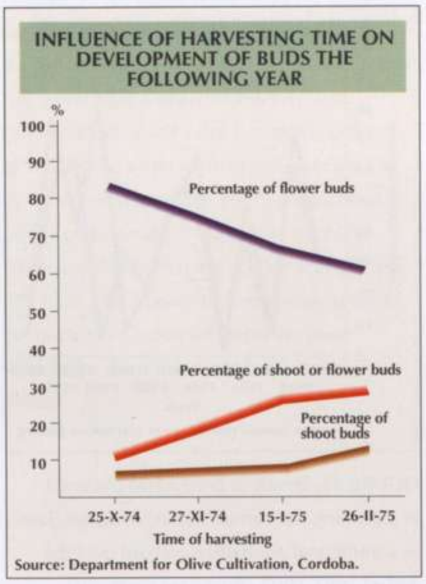


FIGURE 35. Trends in production obtained in a pruning test carried out in Mengibar (Jaén) in a traditional adult olive orchard over the period 1981-1993 comparing traditional biennial manual pruning and biennial mechanical pruning using a disc mower. After 1988 manual cutting was also carried out every four years using a power saw to remove suckers and dry wood from inside the tree.

Olive harvesting with beating.
The olives are knocked off the branches onto nets spread under the trees.


INFLUENCE OF HARVESTING TIME ON DEVELOPMENT OF BUDS THE FOLLOWING YEAR

Source: Department for Olive Cultivation, Cordoba.

FIGURE 36. Influence of harvesting time on development of buds the following year.

olives dropping to the ground resulting in damage to oil quality, fruit loss and increased harvesting costs.

The effect of harvest timing on production in subsequent years

Determining when to harvest and which method to use will have repercussions on production in subsequent years. This is the experience of olive growers and has been demonstrated by many researchers. Early harvesting by beating the trees with poles gives smaller crops in subsequent years; these negative effects are closely linked to the weight of the branches knocked down (Table 10). In early harvests, olives harvested with a shaker give a higher yield the following year than those in which the olives are knocked off by beating (Humanes et al., 1977).

When harvesting is delayed significantly beyond the Critical Harvest Time, interference occurs in the physiology of the olive, with accumulation of nutrient reserves, or in flower differentiation, and there is a major depletion of flower buds (Herruzo et al., 1975), Figure 36. This results in crop reduction (Humanes et al., 1977) as shown in Table 11.

Analysis of the main aspects determining when to harvest olives for oil shows that the most beneficial effects are achieved if it is performed during the Critical Harvest Time. It should not be delayed so that as much fruit as possible is harvested at the optimum moment and in order to avoid fruit dropping to the ground, which prevents top quality oils from being obtained.

When to harvest for table olives

Green olive harvesting is done when the colour starts to change from leaf green to yellowy or slightly golden green. It should be over by the time a violet blush appears on the epicarp. If the olives are to be treated for eating as black olives, the harvest may be prolonged until the turning colour period begins but before the oil content rises or the flesh loses its firmness and particularly before the frosts.

In olives harvested and consumed when black, the harvest should begin when the olives are between purple and jet-black, before they turn soft as a result of frosts or because they are overripe.

TABLE 10

INFLUENCE OF TIMING AND OF MANUAL HARVESTING METHODS ON YIELDS IN SUBSEQUENT YEARS

Average for six crop years (1972-1978). cv. Picual

Treatment	Av. production kg/olive	Twigs kg/olive	Twigs/olive ratio %
Beating (December)	25.28 b	4.50 a	17.80
Beating (January)	30.11 a	4.85 a	16.11
Beating (February)	31.81 a	4.20 a	13.20
Picking (December)	31.56 a	1.95 b	6.18
Picking (January)	29.12 a	1.35 b	4.64
Picking (February)	31.30 a	0.99 b	3.16

The values followed by different letters show statistically significant differences (5%).

Harvesting in December two weeks before CHP

Harvesting in January two weeks after CHP

Harvesting in February six weeks after CHP

Source: Civantos and co-workers, 1992.

HARVESTING METHODS

Olive harvesting has traditionally been performed manually. The cost of labour, the difficulty of ensuring that enough labour is available at the right time in some olive-growing regions, the difficulty of the work or the right timing, are some of the reasons which have led to the search for new, mainly mechanised systems. In the last decade of the 20th century, both methods coexist and are as follows:

Manual methods

- Picking or knocking olives from the trees.

Careful manual picking is the oldest and least harmful method for both the tree and the olives. The workers located round the tree drop the olives into bags or onto nets placed on the ground. Ladders are used to reach the top of the trees. Work is slow and expensive. This system can only be used when cheap labour is available and for top-quality table olives fetching high prices. Simple devices such as rollers, combs, etc. or hand protection all contribute to faster picking, but it is less meticulous and more damage is done to the tree and the fruit.

Harvesting by beating the branches was introduced in an attempt to improve picking speed and was accepted in many regions, mainly for economic reasons and because there was less manual labour available. In some areas olives are knocked down with a stick, doubling or even tripling speed compared with the 'milking' system. However a large number of twigs are knocked down with the olives, particularly at the start of ripening, and it is therefore thought to encourage alternate bearing. Damage to cultivars sensitive to *Pseudomonas savastanoi S.* make it easier for the disease to penetrate causing major losses.

Sometimes, before the olives are knocked down, the trees are treated with products which enhance abscission in order to reduce damage and improve results (Lavee, 1976; Fiorino et al., 1975; Herruzo et al., 1975; Panaro and Pasqualone, 1975; Housni, 1978, Martín, 1986). However, increased leaf fall and high costs have meant that this is seldom done except for research purposes.

Olives knocked down with poles fall on wide nets spread out under the trees. The cost of knocking down the olives includes moving the nets and

TABLE 11
INFLUENCE OF HARVESTING TIMING ON YIELD THE FOLLOWING YEAR

Date of harvesting	Production 1976-1977 Kg/olive
5 Nov. 1975	33.8 A
10 Dec. 1975	34.0 A
13 Jan. 1976	36.0 A
27 Apr. 1976	5.7 B

The values followed by different letters show statistically significant differences (5%).

Source: Cordoba Department for Olive Cultivation. Taken from Humanes et al. 1977.

Detail of the multi-directional trunk shaker head used for mechanical harvesting of olives.

removing the fruit from them. The beating method can amount to savings in some regions of 25% to 30% compared with the manual picking (or milking) method.

- Picking dropped olives off the ground.

If harvesting is done when the fruit is very mature, there may be a large fall to be picked off the ground. The result of the harvest depends on the density of the fallen fruit, the type of ground (topography, stoniness, texture), spontaneous plant cover and the labour efficiency. Harvesting on compact, grass-free soil can be four times more efficient than when the ground is uneven and grassy (Figure 37).

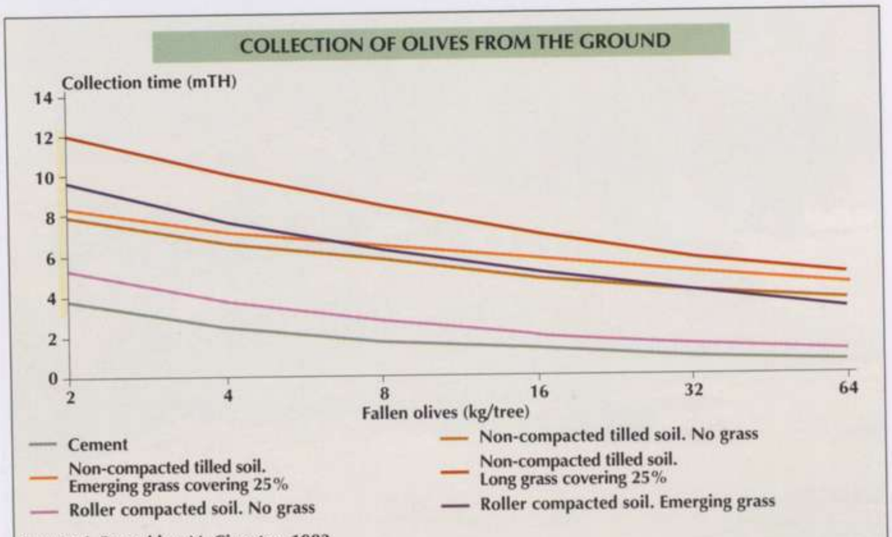
The ground should be prepared by making it more compact and by removing weeds from under the trees using preemergence or postemergence herbicides, as necessary, as long as they are not damaging for the olive trees and do not leave residue in the ground. The application of herbicides should be done before fruit drop to prevent any residue from reaching the oil mill (Valera and Costa, 1990). On well-prepared ground, tools such as brooms, rakes and even purpose-built rollers can be used. Swept-up olives have a great deal of contact with the ground, and earth and stones get among them, damaging the quality of the resulting oil. Olives which have fallen to the ground give poorer quality oils and should be transported and processed separately from those picked from the tree. In some olive-growing regions growers wait until the olives drop naturally to the ground before performing partial harvests. In order to reduce quality loss, the ground is covered with light nets to prevent the fruit from coming into contact with the ground. This method requires high investment in coverage material.

Mechanised methods

- Removing the olives.

Harvesting olives manually when none have fallen to the ground involves 55% of the time being spent on picking the fruit, so from the start the main benefits of mechanisation have been the faster picking rate based on systems used for other larger fruits.

Shakers have developed from the cable model to inertia models, and have been perfected using a multidirectional shaker where shaking is generated



Source: J. Benavides, M. Civantos, 1983.

FIGURE 37. Collection of olives from the ground.

by the stroke of two excentric masses. The power varies constantly resulting in a change of module and direction, which makes it more efficient in removing the olives since different trees require different degrees of shaking.

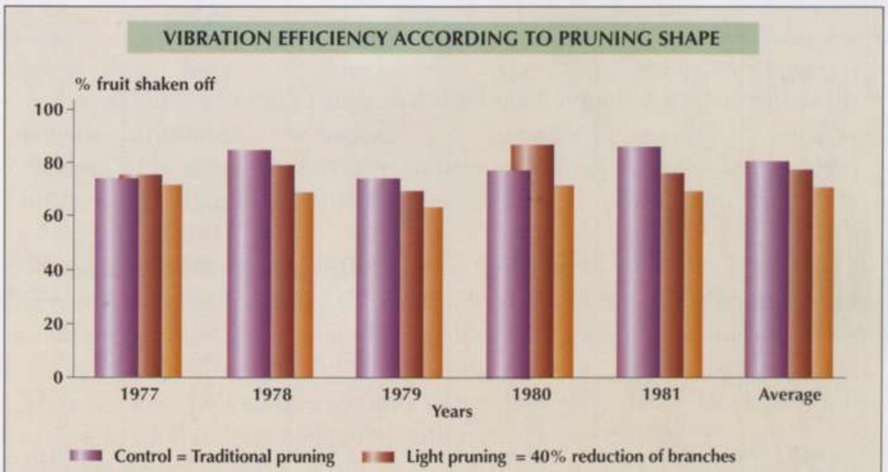
A multidirectional shaker consists of the following items: a transport vehicle (self-propelled or mounted on a tractor), anchorage on the vehicle, arms for lifting and lowering, a support system for the vibrator, a vibrating head with casing, a power transmission system, a clamp device with opening and closing mechanisms as well as pulleys and counterweights to generate vibration.

Shaker movement is achieved by hydraulic equipment consisting basically of an oil tank, a filter, a hydraulic pump operated by the reciprocating engine which sends the liquid under pressure to the distributors and to the hydraulic engine which transmits the drive to the counterweights causing the vibration. The characteristics of the vibrations depend on the hydraulic system (Porras, 1987).

Olives fall when the acceleration reached exceeds resistance to fruit fall/mass of the olive fruit. Insufficient shaker power to produce the right degree of acceleration required can cause breakage of the stalks as a result of material fatigue, and shake down twigs and leaves. Transmission of the vibration from the head to the fruit is hampered by internal cushioning forces (structure of the olive) and external forces (air resistance), by the natural frequency of the fruit and the stalk, and the characteristics of the wood. A high degree of moisture increases the cushioning forces and decreases the resistance of the bark. This may lead to major damage of the attachment point (Martin, 1986).

Trunk and/or branch shakers, particularly multidirectional shakers, give best results and are the most commonly used in practice, although they do have some drawbacks (Porras, 1987) which are gradually being corrected by both researchers and manufacturers. There is a tendency to design shakers with a light headstock for mounting on ordinary farm tractors of 40-60 CV, and single-direction shakers are regaining popularity for olives with a smaller trunk diameter because they have a less complex structure and are therefore less costly (Amirante, 1981). Another trend is to install new hydraulic circuits with hydropneumatic energy accumulation on shakers to

For full mechanisation of olive harvesting, trees should have a single trunk to increase the efficiency of vibrators which to date are the only machines capable of resolving the problem of olive harvesting. The tree in the photograph is cv. Galego (Portugal).



VIBRATION EFFICIENCY ACCORDING TO PRUNING SHAPE

Source: Loreti and Vitagliano, 1984.

FIGURE 38. Vibration efficiency according to pruning shape.

TABLE 12
SHAKER HARVESTING. INFLUENCE OF YIELD ON EFFICIENCY
cv. Chemlali

Production Kg/olive	Olives shaken off %
111.3	81.33
111.0	83.39
96.6	89.53
58.3	94.34
56.9	89.20
51.4	95.76
36.00	87.81
32.66	84.94
22.00	91.90
20.00	92.00
14.00	92.20

Source: Ouksili and Hamadouche, 1978.

create the same effect during vibration as high-powered machinery without having to install reciprocating engines of over 50 CV.

All the olive-producing countries are monitoring the achievements of commercial shakers with varying results, since orchard conditions also vary (see Tables 12, 13, 14 and Figure 38).

Shaker efficiency improves when the volume of the tree is lower, when the diameter of the trunk is smaller, when the fruits show less resistance to dropping and greater weight and, in particular, when the ratio between the two parameters is lower. Single-trunk training with the scaffold branches at sharp angles and pruning which promotes erect branches, as well as fruits with short stalks, are other favourable points. The greater the coincidence between the olive tree to be shaken and the ideal, the better the shaking results.

Shaking efficiency increases as from the Critical Harvest Time but, since natural drop also increases, the proportion of olives harvested with the shaker decreases (Table 15). The period recommended for harvesting using a shaker ranges from the time when the olive has formed most of its oil to the time when there is an increase in natural fall and, though this varies depending on the cultivar and the weather conditions, the period seldom exceeds 45 - 60 days.

- Collecting the fruit.

In most cases shakers for releasing olives are used in combination with movable nets placed underneath the trees, as for the manual system. The picking crew usually consists of 7 - 9 workers. Mechanised fruit collection is carried out by means of:

– Shakers which incorporate a metal frame with a net shaped like an upside-down umbrella which is spread around the tree so that the olives fall into it.

TABLE 13
FOLLOW-UP OF OLIVE HARVESTING USING TRUNK SHAKERS
Province of Jaén (Spain). Cv. Picual. Omi shaker. 1973 crop year.

Concept	Cortinas	Almedina	Uribe	Casarejo	C. Estepa	S. Rafael	La Encina	Laguna
Production Kg/tree	37.16	28.61	39.9	20.41	44.03	58.48	31.98	42.52
No. trunks/olive	1.4	2.8	2.3	1.5	2.7	2.3	2.1	2.9
No. olives harvested	1,386	369	1,340	1,276	603	262	251	695
Kg. shaken off	41,109	7,714	27,603	19,482	17,616	8,250	4,290	26,059
No. days	8	5	11	7	7	3	3	6
Total hours	39h 10m	27h 16m	48h 29m	32h 42m	32h 51m	10h 10m	12h 25m	28h 07m
Hours/day	4h 54	4h 27	4h 24	4h 40	4h 41	3h 33	4h 08	4h 41
Olives/day	174	73.8	121.8	182.2	86.1	87.3	117	115.8
Trunks/day	236	207	276	270	235	198	250	267
Kg/day	5,139	1,543	2,509	2,785	2,617	2,750	1,430	4,360
Olives/h	35.4	13.5	27.7	39.1	18.4	25.8	28.2	24.7
Trunks/h	48	38	63	58	50	59	60	57
Kg/hour	1,050	283	272	418	536	812	346	929
Kg shaken off/tree	29.7	20.9	20.6	15.3	29.2	31.5	12.2	37.6
Kg shaken off/trunk	21.8	7.4	9.1	10.3	10.7	13.9	5.7	16.4
% fallen naturally	10.8	12.7	26.8	14.0	18.6	43.2	61.4	28.0
% shaker efficiency	89.5	81.9	70.6	87.3	81.6	94.8	99.1	91.6

Source: Civantos and co-workers, 1973.

TABLE 14
TREE CHARACTERISTICS, WORKING TIMES AND TEAM PRODUCTIVITY
IN MECHANICAL OLIVE HARVESTING

		Andria (Bari)		Veglie (Lecce)	
Cultivar		Coratina		Ogliarola	
Age		80 years		40 years	
Plant density		11x11 m		14x14 m	
Trunk					
– height	cm	116		133	
– diameter	cm	32		29	
Canopy					
– height	cm	448		355	
– diameter	cm	451		512	
– volume	m3	71		73	
Production	Kg/tree	39.8		56.0	
Av. fruit force	g	2.30	2.20	1.14	1.15
Detachment force	N	4.8	6.0	6.6	7.5
Force/weight	N/g	2.1	2.7	5.8	6.6

		Andria (Bari)		Veglie (Lecce)	
Shaker used		Cecma with nets	and SR12	Cecma with nets	and SR12
Labour					
– with shaker	nº	1	1	1	1
– with nets	nº	4	0	10	0
– total	nº	5	1	11	1
Harvesting efficiency	%	73.5	55.4	54.0	63.0
Total time taken:					
– shaker team	min/100	122.4	336.4	126.0	445.3
– net team	Olives	240.8	0	183.2	0
Operating time	min/tree	2.4	3.4	1.8	4.4
Team productivity	tree/h	5.0	17.8	3.0	13.5
per person	Kg/h	146.3	392.5	90.7	476.3

Source: Giametta, 1984.

TABLE 15
EFFICIENCY OF OLIVE SHAKING IN RELATION TO TIMING
1975-76. cv. Hojiblanca

Harvesting date	Production Kg/olive	Shaker efficiency %	Natural fruit fall %	Fruit harvested by shaker %	Resistance to detachment g	Shaking time sec/trunk
5.11.75. Green olives	59.3 B	88.84 A		88.84 A	682 B	8.6 c C D
10.12.75. Olives turning colour	64.3 B	92.21 A		92.21 A	553 A	9.2 c C
13.1.76. Black olives	62.9 B	90.66 A		90.66 A	676 B	7.6 b D
27.4.76. Black olives	81.0 A	91.70 A	40,19	54.84 B	305 C	5.5 a A

The values in each column followed by different letters show stastically significant differences: capitals 1%, small letters 5%.

Cource: Humanes and co-workers, 1977.

- A flat, sloping catching frame installed on a separate tractor which propels the fruit towards the hopper.
- Trailers with lateral shafts carrying nets that are opened out by the operators and rolled up by the tractor p.t.o.

- Mechanical collection of fruit fallen to the ground.

The mechanical collection of olives which have fallen to the ground requires careful preparation of the ground. The following types of machinery are used:

- Sweeping machines which leave the olives in rows or piles on the ground. They are then picked up manually or mechanically. Table 16 shows an increase in productivity compared with manual harvesting.
- Blowers which sweep and pile up fallen olives using air currents at a tangent to form a belt. These range from small backpack devices to self-propelled machines.

TABLE 16
PRODUCTIVITY OF MECHANICAL SWEEPERS AND MANUAL SWEEPING

		Mechanical sweeper	Manual sweeper
Equipment used		Majocchi sweeper (1 worker)	Metal rakes (3 workers)
Productivity per worker	Olives/h	32.89	7.91
	100 Kg/h	6.51	1.57
Worker time	min/100 Kg	9.2	38.10

Source: Giametta, 1984.

- Vacuum collectors for olives which have been piled up or left in rows. There are also other machines with two rollers revolving in opposite directions, or a brush fan which lifts the fruit onto a conveyor.
- Collectors which perform more than one of these operations, sweeping and suction or sweeping and collection, and which deposit the fruit in containers or hoppers after initial cleaning.

- Mechanical cleaning and washing

The picking method partially determines the cleaning treatment given to olives before processing. When the olives are picked straight from the tree and collected in nets, the foreign matter collected with them consists mainly of leaves and shoots. Any of the cleaning machines available on the market can be used, ranging from the small cleaners propelled by tractor power and used in the orchard, to large machines installed permanently in the cleaning plants.

Olives picked off the ground need to be washed to remove the large quantities of impurities, and because the jostling and bruising damages the epicarp and impurities get into the flesh. If the ground is wet during harvesting, they may be muddy. The washing machines separate the foreign matter from the olives by virtue of the different densities (by adding sodium chloride to the water) or with water currents. These are complex machines that are difficult to take to the orchards so are installed in washing plants.

- Machine harvesting of table olives

Green table olives are harvested in a different way to that used for olives for oil or for black table olives. When harvesting starts, resistance to fruit fall is high and the shakers are less efficient (Aggabio et al., 1989; Ouksili and Sadouni, 1986; Herruzo et al., 1977). Experiments have been performed with abscission products to increase shaker efficiency (Oiksili and Sadouni, 1986), but these cause major leaf fall and chemical damage has been found in the olives remaining on the tree after the process (Heruzzo et al., 1977). This raises doubts about the use of abscission-enhancing products which may also leave behind residue in the olives.

Shakers damage the olives because of bruising with other fruit and branches, or from bruising in the collection bins and from the shaker itself (Humanes et al., 1978; Aggabio et al., 1989). By shortening the time between harvesting and the start of processing with sodium hydroxide, damage to shaker-harvested olives can be reduced to levels similar to those encoun-

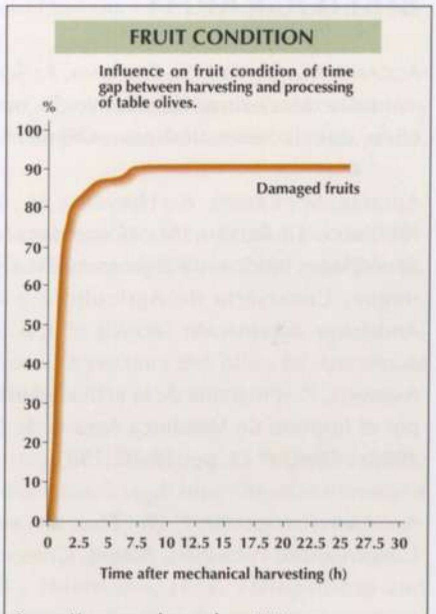
Dirty olives being transported to the processing plant for washing.

TABLE 17
HARVESTING OF TABLE OLIVES WITH MECHANICAL SHAKER
Proportion of damaged fruit. cv. Hojiblanca

Estate	Interval between harvesting and start of processing			Manual harvesting during same day
	1 h	6 h	24 h	
La Isla	21.6	37.5	55.2	18.3
Galeón	14.7	30.8	52.5	11.4
Cda Hermosa	8.7	21.6	35.1	12.4
Cerradillo	9.7	22.8	37.3	13.6
AVERAGE	13.7	28.2	45.0	13.9

Source: Humanes and co-workers, 1978.

tered in hand picking, as long as the olives are processed immediately (Humanes et al., 1978) (See Table 17 and Figure 39). Olive damage caused by falling onto the nets is reduced when the nets are hung in the air so that they do not touch the ground and also when padded collection systems or deceleration bands fixed on the surface of the nets are used (Agabbio et al., 1989; Humanes et al., 1979; Lombardo, 1990).



Source: Humanes and co-workers, 1978.

FIGURA 39. Influence on fruit condition of time gap between harvesting and processing of table olives.

OLIVE CONSERVATION AND PROCESSING

After the olives have been picked, they should be processed as soon as possible. The harvest should be delivered to the mill daily. Any delay from piling or lack of aeration may lead to hydrolytic, lipolytic or oxidation processes that are damaging to oil quality. It is always better to stack the olives in boxes or in small, even piles rather than putting them in sacks or piling them up high.

Olive growers should bear in mind that olives picked straight from the trees give higher-quality oils than those picked off the ground. They should be kept apart during picking and transported to the mill in separate containers. Olives that are muddy or mixed with stones and soil should be carefully washed as early as possible.

When the olives reach the mill they should be graded. To facilitate this they should be separated according to variety or degree of maturity. Pest-damaged or diseased olives should be kept apart from healthy olives, and jostled and badly bruised olives should be separated from olives in good condition (Civantos et al., 1982).

The olives should be placed in strong, washable, plastic boxes for transport from the orchard to the mill.

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Chapter 5

AGRONOMIC TECHNIQUES AND CHARACTERISTICS OF OLIVE OIL

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AGRONOMIC TECHNIQUES AND CHARACTERISTICS OF OLIVE OIL

PIERO FIORINO

The olive has one special characteristic: its fruit is always consumed after processing of one kind or another.

Such processing ranges from simple brine treatment to the removal of bitterness by fermentation or sweetening with chemical compounds. Table olives are sometimes prepared with aromatic dressings, darkened or dried or served as olive paste. In Italy, only one cultivar gives fruits that are edible directly from the tree (cv Mele or Dolcemele), but its origin is not clear and it must be treated as a mere curiosity.

Oil is a product of the olive but it represents only the lipid fraction and not the characteristics of the fruit as a whole. Oil production has traditionally been greatly affected by factors such as bad weather, pests and the slowness of the process itself. On occasion, the final product is only just edible because the objective in the past has always been to extract the greatest possible amount of oil.

The location of most olive cultivation has helped to keep the panorama static. In the Mediterranean basin, where olive growing is traditional, tastes were (and are) adapted to the local products whereas, outside the Mediterranean, in the few cases where cultivation has been successful it has been predominantly for table olives. In addition, the facility of multiplication, longevity and vitality of the so-called 'immortal' trees, plus the length of the juvenile period have reduced natural evolution and invevitably held back efforts at improvement which have been successful for other species.

Against this background, in the last fifty years, efforts have focused on rationalising cultivation by recovering some of the traditional plantations and through a revival of olive growing in more favourable areas. Whereas the requirements for table olives are clear, the criteria for oil olive orchards differ depending on the socio-economic development of the area in question, the agricultural, technical and weather conditions or even, more rarely, the characteristics of the finished product. Such criteria made it necessary to plant local cultivars in certain specific areas where they could be relied on to be hardy enough to withstand stress conditions while giving high yields and being easy to propagate. As a result, insufficient attention was paid to the organoleptic characteristics of the fruit and its products, although this was the main priority with other species.

The prevailing commercial criterion is still to take acidity as the main factor for determining the value of an olive oil. Only in 1991 (Official Journal of the European Communities of 5 September 1991, no. 34 L 248) did EEC standards first introduce other chemical and organoleptic parameters. Certain countries have begun to apply «controlled denomination of origin» and in Italy this is the case for extra virgin and virgin oils (Official Journal, General Series; of 5 February 1992 no. 49 L 169).

The extensive literature on the composition and characteristics of virgin olive oil is constantly being enriched as analytical and identification capabilities improve. Compounds can now be detected down to ppb. Many chemical families are assessed for their rheological and nutritional importance, others because they help to discriminate virgin oil from oils of diverse origin or non-virgin oils. Depending on the presence and quantity of specific complexes, an oil may differ either in its triglyceride composition or because of the fraction of un-saponifiable matter and of minor polar compounds in a series of combinations that make the chemical and commercial classification of oils very difficult. Each country establishes the chemical characteristics that define its edible olive oils and the criteria to be followed for commercial classification.

For further information on olive oil composition, its medical and biological uses and the characteristics of virgin olive oils, see the literature and in particular the works of Christakis et al. (1982), Tiscornia et al. (1982), Modi et al. (1991), and Viola (1991).

QUALITY PARAMETERS AND VALUES

The richness of composition, flavour and colour, which are typical of a natural product, depend on the characteristics of the genetic matrix (for most olive populations) inter-acting with the environment. In addition to this interaction, cultivation practices and extraction systems contribute to create the great variety of chemical and organoleptic characteristics which in turn make the market so varied.

The factors affecting not just the yield of the trees but also oil composition all help to determine the end result of the crop, increasing the number of trade categories beyond those covered by the standards, as well as the quality level of certain products within the same category.

In general, the term 'quality' is used when the characteristics of the product conform to certain basic requirements. In many languages, the term has a positive connotation which, without referring to any particular characteristic, expresses an assessment based on the sum of certain important values and various characteristics linked to the nature of the product itself.

With respect to virgin olive oils, it is worth checking which attributes should be taken into consideration when referring to quality because experts, producers and distributors tend to make no distinction between terms such as 'purity', 'authenticity', and 'typical characteristics' using them as synonyms of 'quality', whereas quality is based on the equilibrium between many different elements.

An internationally accepted standard for food quality (UNI-ISO8402, Galoppini and Fiorentini, 1991; Dionisi and Amelotta, 1992) is based on the presence of and/or compliance with certain requirements both explicit (healthiness, taste, effect on well-being) and implicit (hygiene, food safety, and market-related safety and nutritional value). In addition, olive oil quality can be represented by a combination of the five factors listed below, each of which can be used to evaluate levels of specific characteristics:

a) lack of defects
b) purity (absence of residue)
c) authenticity
d) chemical equilibrium
e) typical characteristics

By so arranging the different characteristics involved, it is easier to quantify the constituents of an abstract concept such as the 'total quality' of a natural food like extra-virgin olive oil. These positive traits have to be considered in addition to standard precautions and requirements for any food product; for example, purity (i.e. the absence of residue) should not be taken to refer only to residue from plant health treatments, levels of which are defined by strict legal stipulations, but also to any foreign element or any anomaly in the oil composition caused by incorrect production, processing or conservation.

Of the five factors considered, two (a and b) are applicable for any kind of food; the next two (c and d) represent the generic factors that apply specifically to olive oil, and the last (e) is related to the culture and dietary habits of the various regions. The first four (a, b, c and d) can be assessed relatively easily with appropriate instruments, while the fifth (e) can be identified and safeguarded by a mixed system of analytical instruments and administrative actions, with widely varying margins for the definition of requisites, some of which are related to subjective perceptions such as colour, taste and aroma.

LACK OF DEFECTS

For the identification of defects, a rather complex analytical method is used, in addition to organoleptic assessment (EEC Regulation 2568/91, Official Journal of the European Communities of 5 september 1991 No.34L 248). It must be stressed that the term 'defect' may refer to a natural attribute that standards do allow but that is not desired, either because it is too intense or too weak, or simply because of a concern to bring down the tolerance limit of certain values – the primary concern being that as balanced a product as possible should reach the consumer.

Two fundamental parameters are used to define defects: acidity (expressed as oleic acid in %) and the Panel Test (Gonzales-Quijano, 1990) which aims only to determine the presence of defects resulting from incorrect production, harvesting or processing (Solinas, 1992). These two references are used to measure the attributes of the oil and check on virtually all the phases in its life. Some authors (e.g. Mattei, in press) have suggested that the peroxide value should also be taken into consideration at this point.

Acidity is an important parameter not only in itself but also as an indication of good production and extraction technology. The basic acidity of oil is about 0.2% (expressed as oleic acid) and any increase in this value indicates that some type of incident, albeit slight, occurred before the oil was formed. The three categories of virgin oil are currently separated by one point (1%) of acidity but this interval generally involves substantial differences in taste and aroma which do not vary in direct proportion to the factor being measured.

The Panel Test assessment, as it appears in the EU standards, does not seem very appropriate for the identification of those special flavours that go to make up the individual and educational component which is attributed to the use of olive oil. It is, however, useful for identifying oils with organoleptic defects caused by errors during production, either after harvesting or during the processing and conservation phase (Michelakis, 1992).

The Panel Test was established and launched officially by the International Olive Oil Council (IOOC) in 1987 and consists of an evaluation by a panel (comprising 8 to 12 expert tasters) that aims to issue as consistent an assessment as possible as to the presence and intensity of gustatory attributes in each sample. The data are processed in a simple statistical manner (variance), to establish repeatability by means of a mechanism implicit in the method and, if there are highly contrasting opinions, it is necessary to revise or repeat the test. The profile sheets are drawn up and the ratings formulated to stress the presence of defects which may cause the downgrading of an oil. The choice of expert, rather than random, tasters guarantees protection against defects (it is not by chance that an extra virgin oil is considered suitable when it scores at least 6.5/9 before chemical analyses); but the Panel Test may influence the evaluation of desired characteristics which depend on consumer tastes that may vary depending on the region, level of education, diet, sex, etc.

PURITY

The absence of residue is a prerequisite that is controlled by strict legislation and is enforceable by accurate methods that are currently being improved (Tiscornia, 1992). The concept of purity covers the absence of any type of substance that may have entered the oil during harvesting or decantation, or from the containers. The stability of olive oil makes it safe when newly-pressed (by physical separation) and subsequently, and no special treatments are required to ensure conservation.

AUTHENTICITY

The authenticity of olive oil is also stipulated by law. It guarantees that the oil has been obtained from the fruit of the olive tree, solely by mechanical or other physical means of separation, without any heat treatment (which can change the characteristics of the product).

The composition of virgin and, in particular, extra virgin olive oils is based on triglycerides, together with a characteristic complex fraction which is unique for its biological and psycho-sensorial properties. Extra virgin olive oil is particularly expensive to produce and thus may reach the market at fairly high prices. Precisely because of the difference in value between virgin oils and seed oils or oils made from defective olives or olives that have been specially treated to be re-introduced into the production cycle, fraudulent blending is often carried out to get round authenticity tests. Although this type of fraud is now easier to detect as a result of improved analytical technology, stricter controls and research, such blends are still difficult to control if they have been carefully carried out (Tiscornia, 1992) and, in cases of self-supply and small-scale local trading, often escape notice. These practices are not only fraudulent from the consumer point of view but also are a form of unfair competition and discourage the improvement of cultivation methods.

CHEMICAL EQUILIBRIUM

Chemical equilibrium, in the wide sense of the term, refers to the presence, levels and ratios of substances which give the oil consistency, taste, preservability and salubrity. 'Ideal' constituents (Petruccioli, 1988) have been identified whereby a good oil should contain balanced amounts of acids, vitamins, etc. and should have the right ratios between the minor constituents that cause variations in freshness, colour, etc.

The presence and levels of specific chemical complexes can be used to establish selection criteria even for oils within the same commercial category. It is well known that oils rich in saturated fatty acids are more viscous than those with a high content of unsaturated fatty acids, while flavours and aromas are due to specific chemical families (aldehydes, hexanols, carbonyls, phenols).

Moreover, olive oil naturally contains groups of substances (tocopherols, phenols) that are micronutrients and antioxidants and act as regulators and protectors of the human metabolism. On this basis, studies have been made into complex correlations to identify objective indices for the classification of oils. These indices may be analytically very fine, such as the determination of the carbonylic constituents of aroma, the aim being to provide a Global Quality Index (QI or GQI) (Solinas, 1987) based on objective parameters and taking into account the value of the sum of the numerous constituents equalised by a conversion factor F and formulated as indicated in Table 1.

The parameters were chosen for their commercial importance and equalised, as amplitude and distribution of intervals, in relation to the Panel Test score with a correlation determined from a maximum variation of 5

TABLE 1
ONE OF THE FORMULAE FOR THE QUALITY INDEX (QI)

**QI=F{1/AC+1/PV+1/CV+1/K270+HT+1(alpha-TP)+
+1/(beta-%lin)+1/(gamma-K664/k446)} (Solinas, 1987)**

AC = acidity
PV = peroxide value
CV = volatile carbonyl value
K270 = absorbency at 270 nm
HT = hydroxythyrosol
alpha = ideal total phenol value
TP = total phenol value
%lin = percentage of linoleic acid
beta = ideal percentage of linoleic acid
gamma = ideal colour ratio value
K664/K446 = colour ratio in the sample

This sum still contains too many subjective factors in the «ideal quantities», and a simplified formula has been recommended (Solinas et al. 1990) using linear functions of the acidity values, of the spectrophotometric analysis (K270), or the peroxide value, of total phenols and of the Panel Test rating giving the GQI as shown in Table 2.

TABLE 2
GLOBAL QUALITY INDEX (GQI)

GQI = YA+YB+YC+YD+PT

yA acidity value (x between 0.1 and 3.3) according to the function yA = 9.2-1.6x;
yB peroxide value (x between 1 and 15) according to the function yB = 9.4-0, 36x;
yC K270 spectrophotometric value (x between 0.07 and 0.25) according to yC = 10.9-27, 7x;
yD phenol value (x between 400 and 4) for yD = 3.44 + 0.014x;
Pt Panel Test value (by Solinas et al. 1990).

points in the panel rating considering a value of 4 in the test as the minimum for an edible oil (9 max – 4 min = 5 = foreseeable variation).

The structure of the formula presents a few problems, especially because there are no linear relations in the variations of the different parameters and because little consideration is given to the natural components (e.g. tocopherols). But, if the principle is accepted in trade standards, the criterion of the lack of defects will be superseded and oils will be chosen according to parameters representing taste (panel test and phenols), keeping qualities (peroxides and phenols) and the evaluation of general production and extraction attributes (acidity and extinction at K270). The same concept is expressed with a slightly different formula in the Overall Quality Index for virgin olive oils drawn up by the IOOC with the cooperation of several research institutes and laboratories in various olive-growing countries and given in Table 3.

TYPICAL CHARACTERISTICS

The typical characteristics are turning out to be the most difficult aspect to define, as unconscious factors which substitute what is desired for what is good come into play. This is inevitable in products with original natural flavours and a series of tastes, aromas and colours which probably strike at a subliminal level, invoking a general sense of times gone by, of the home and of a cultural environment, so much so that slight defects or excessive flavours that are not generally considered pleasant may be judged by some to be indispensable.

The typical characteristics of a product result from the interaction between genetic, technical and environmental matrices, and can thus be defined and controlled by means of a combination of laboratory and administrative instruments. Geographic limits within a district are set to establish homogeneous areas for certain productive or climatic factors within which production and extraction techniques can be carefully monitored to obtain a product with definable and repeatable typical characteristics. The sale of such products is governed by tighter controls than those in the ordinary trade standards. Areas classified as Protected Denominations of Origin or Protected Geographical Indications have been set up within the EU (Regulation (EEC) 2081/92, Official Journal of the European Communities of 24 July 1992, No.208).

More detailed characterisation of olive oil is likely to mean that serious attempts at fraud will increase. Furthermore, with respect to authenticity, if «objective quality control of an extra virgin oil is on the whole rather difficult» (Tiscornia, 1992), it is also true that no parameters for 'typical characteristics' have been established nor analytical methods for checking the accuracy of claims (Dionisi and Amelotti, 1992). Important research is currently being conducted to identify parameters capable of measuring the 'typical characteristics' in specific areas. At our current state of knowledge, however, the information about variations between zones and years is too limited and repeatability and reliability are insufficient to protect at least the majority of production from possible fraud.

TABLE 3
OVERALL QUALITY INDEX (OQI)

(OQI) = 2.55+0.91SA - 078AV - 7.35 K270-0.066PV

SA = Sensory analysis (Panel test)
AV = Acid value (% of oleic acid)
K270 = Specific extinction at 270 nm
PV = Peroxide value

Similarly, the Panel Test can be contested precisely because of the different evaluation applied to the same 'positive' attributes which are still difficult to determine physically and to set administratively. In addition, many data vary as a result of the presence of cultivar populations in many areas which are only partially known and variations in production and extraction technologies, each of which, «may, with the same agronomic factors, have an effect on the final composition of the oil, giving rise to general differences in quality to a greater or lesser extent». (Montedoro, 1992).

BIOTIC FACTORS AND AGRONOMIC CHOICES INFLUENCING THE PRODUCT CHARACTERISTICS

The four major factors governing a product, not only from the point of view of quality but also for the characteristics of the oil are: the cultivar, the cultivation environment, the cultural techniques applied and the method of extraction.

Each of these may affect:

- lipogenesis (yield and composition);
- the levels of and ratios between the liposoluble compounds forming the majority of the unsaponifiable fraction of the oil;
- the levels and ratios of the chemical compounds in the fruit or formed during extraction that are characteristic of the taste and aroma of the oil and that enter it in different ways (simple and complex phenols), according to the interaction between the state of the fruit and the method of extraction.

The characteristics caused by the first two factors (cultivar and environment, i.e. the biotic factors) can be enhanced and controlled in the orchard to some extent but those caused by agronomic techniques and extraction technology can be manipulated more directly, within the limits imposed to protect human health and the environment.

BIOTIC FACTORS

Environment

The term 'environment' refers on the one hand to a vast area characterised by climatic conditions capable of modifying spontaneous vegetation in a homogeneous manner and of directly affecting cultivation. In a more restricted sense, it refers to a geographical area defined by similar meso-climatic conditions. For the application of specific techniques or the obtention of particular agronomic results, 'environment' can also refer to the orchard location, with specific emphasis on soil characteristics, incline and exposure.

For major areas, research has shown (Christakis et al., 1982) that the acid composition of oils can vary (Table 3) depending on the origin. Data prior to 1975 referring to traditional orchards are fairly representative (in terms of numbers) even though the analytical techniques are not entirely comparable to those of today. The data point to the great variability of Greek oil and the relatively low oleic acid content in oils from warmer areas (Greece and Tunisia) compared with products from the Northern Mediterranean. Argentina is classified alongside Tunisia, while Turkey and Israel fall in the same zone as France. Research has also shown that in Tunisia the level of oleic acid falls in line with the latitude, and this tendency seems to be confirmed in Italy as well (Table 5), with a relative increase in linoleic acid (Tiscornia et al., 1982). Similarly, the levels of unsaponifiable matter (sterols, erithrodiol) seem to be linked to the environment (Tiscornia et al., 1982, 1983; Paganuzzi, 1986).

Data from experimental work during the eighties report values which vary widely for the same areas from year to year. In addition to the variability related to origin (environment, specific pattern of climatic conditions), the sampling effect contributes to the dispersion of the

TABLE 4
COMPOSITION OF FATTY ACIDS OF OLIVE OIL
IN % OF TOTAL FATTY ACIDS

Producing country	Number of samples analysed	Oleic acid %	Linoleic acid %	Palmitoleic acid %	Palmitic acid %	Stearic acid %
Greece	> 3.000	57,6-93,5	1,6-23,6	0,5-2,3	7,5-16,0	1,4-3,8
Italy	733	64,1-85,0	1,0-15,0	0,2-5,5	7,1-17,5	0,3-3,4
Spain	75	65,3-79,6	5,1-19,8	—	—	—
Argentina	40	54,0-79,1	5,3-22,7	0,2-3,4	9,8-20,0	0,3-2,9
Tunisia	21	55,2-70,6	9,5-20,1	1,0-2,2	13,9-21,1	1,3-2,5
Portugal	114	69,0-86,0	3,0-14,0	—	—	—

TABLE 5
AVERAGE CONTENT (%) OF FATTY ACIDS
IN ITALIAN OLIVE OILS

	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid
Liguria	10,0	2,6	80,6	5,2
Tuscany	11,6	2,2	77,6	6,7
Umbria	10,9	2,0	79,6	5,9
Puglia	9,3	2,3	79,6	7,3
Calabria	13,8	2,6	75,6	6,0
Sardinia	12,5	2,0	74,6	9,2
Sicily	12,6	2,8	72,9	8,7

data as, owing to its non-reproducible characteristics, it influences the chemiometric determination (Forina et al., 1983).

On a smaller scale, the action of specific environmental conditions is less evident and is probably confused as a result of the fragmentation (of varieties and techniques) which is typical of traditional olive growing (Lavee, 1992), making it very difficult to define the representative sample.

Four different groups were identified among oils from 9 different provinces of Tuscany (Armanino et al., 1984), three of which were linked to easily distinguishable factors such as altitude and distance from the sea, and one which could not be explained in terms of variety or environment. According to Fiorino (1991), the common factor could be the (late) harvesting period.

As to the possibility of establishing geographically-defined environments using chemical parameters and instrumentation, the various researchers are not in agreement, probably because in most such attempts the data refer to compounds of a general type that vary to such a degree during maturation that they lose any real chemo-taxonomic value (Modi et al., 1992).

By means of statistical methods (Aparicio, 1988), the probable environmental matrix may be recognised between relatively close areas (Alessandri et al., 1992), to the point of making it possible to distinguish, for a few compound families, a specific area of production (Alberghina et al., 1991). Only in the last decade have instruments become available which can tackle the problem from the chemo-statistical and 'modellistic' aspect, so as to identify the (probable) origin of an oil. The ambiguity which shrouds all experimental data is due to the lack of knowledge of the biological mechanisms which regulate and control the compositional factors of oil.

If 'environment' is taken to refer to the action of the characteristics of the place of production, a great deal of knowledge still depends on tradition. Many manuals (Pecori R., 1988, La Cultura dell'Olivo, Tipografia Ricci, Florence; Mingioli E., Oleificio Moderno, 1901, Unione Tipografica Editrice, Turin) stress the influence of exposure and the soil type. In general, these texts refer to types of production which are not identified and rarely refer to varieties.

It should be pointed out that oil obtained from hills (Solinas, 1990) is considered to be of better quality than that obtained from plains, and that there seems to be a relation between the structure of the land and the phenol content in Moraiolo oil in Umbria (Servili et al., 1990).

Cultivar

The cultivar is the most important variable characterising olive oil production in terms of yield (D'Amore et al., 1977), speed and method of oil accumulation (Lavee and Wodner, 1991) and the characteristics of the oil (Cimato et al., 1988; Pannelli et al., 1991).

The accumulation of oil is not linked to maturation but can be considered a metabolic incident in the growth of the mesocarp cells, which prematurely activate the triglyceride formation process leading to a predominant formation of oleic acid among the fatty acids. Since they do not have a specific set of enzymes, these mesocarp cells can only accumulate the triglycerides by compartmentalising them. The process lasts, at different rates, up to abscission of the fruit.

The various cultivars influence the chemical profile of the oil through a dual mechanism of i) the accumulation of various triglycerides, and ii) the formation and development of other constituents.

As regards the first aspect, data referring to attempts to characterise varieties show oscillations in the acid composition of the various cultivars and areas. Oleic acid varies between 72 and 80% in the most common variety of Central Italy, while in Sardinia this percentage drops below 70% in the Bianca and Tonda cultivars (Vacca V., 1990) and, in the case of the two Nera clones called «31B» and «52», down to 65%. In Tuscany, Leccino is found to be slightly richer in palmitic acid compared with Frantoio, Moraiolo and Coratina (Cimato et al., 1992). Carolea differs from Frantoio because of its higher stearic acid content (Cimato et al., 1988), while certain lines or varieties have fatty acids with different carbon atoms (C:17=0 and C17=1) and in significant amounts, which can probably be used for characterisation (Modi et al., 1992a).

The production of oleic acid (O) has precedence and substitutions seem to occur predominantly with palmitic (P) and linoleic acid (L). The major variation between cultivars is in linoleic acid content which may oscillate from 2.3 to 23%, while palmitic acid seems to be more stable.

The acid composition of the genetic matrix can influence the interaction (climatic conditions, maturation phases of the fruit). When the variations in the relative ratios between the three major fatty acids are systematically monitored over time, a correlation between P and 0 is seen that is difficult to explain and there is a positive regression in linoleic acid over time. This interaction effects a slow change in the ratios between the various fatty acids. The possible oscillations over time of the analytical values for the various cultivars may overlap for each of these, creating a common zone in the distribution of data (an ambiguity zone, Fiorino and Nizzi Grifi, 1991), within which many oils may fall.

Evaluation of the ratio between oleic and linoleic acid (Panneli et al., 1991), or in more general terms, evaluation of the ratio between unsaturated and saturated acids have been proposed as a means of obtaining a better understanding of the action of the genetic matrix in an oil (Cucurchi, 1965). Such indices nevertheless seem more useful for understanding changes in composition due to the maturation effect than for the purpose of identifying genetic differences (Cimato et al., 1988).

More apparent is the influence of the cultivar in the determination of constituents in the oil that are not derived from glycerides.

This fraction has traditionally been divided into two groups:

- The unsaponifiable group, which comprises compounds that are not soluble in water after saponification and includes the families of hydrocarbons, sterols, alcohols and chromoplast pigments; in many cases they turn out to be esters of the principal fatty acids;
- Minor polar compounds, represented by molecules that are water-soluble to different degrees and that consist chiefly of products of the metabolism of oleuropein.

The effects of the cultivar on the unsaponifiable group have not been studied in depth. The chemical families of this fraction have been studied more for their sensitivity to treatment and handling with a view to guaranteeing the authenticity of virgin oil than with respect to other parameters such as genetic origin.

Hydrocarbons have not been studied extensively in comparative trials, despite their relative abundance (> 1000 ppm). In Tuscany, the oil from Moraiolo has been shown to be richer in hydrocarbons in general and in squalene compared with that from Frantoio, Leccino and Coratina (Modi et al., 1991). Furthermore, saturated hydrocarbons with carbon chains between 23 and 34 atoms, with a predominance of groups between 27 and 31C have been identified in oils from the same region (Mattei et al., 1992).

The oils of Nebbio and Cellina di Nardo are rich in sterols (Camera et al., 1975), with values exceeding 3000 ppm, while the oils of Frantoio and Leccino in Tuscany have a larger content (Modi et al., 1991) than those of Moraiolo and Coratina, although it is still lower than the first two.

This family is highly influenced by the maturation level of the fruit, and their content in oil obtained from a single region may show wavy variations within a single season (Figure 1), probably due to incidental factors, such as the premature fall of the more mature fruit (Modi et al., 1992).

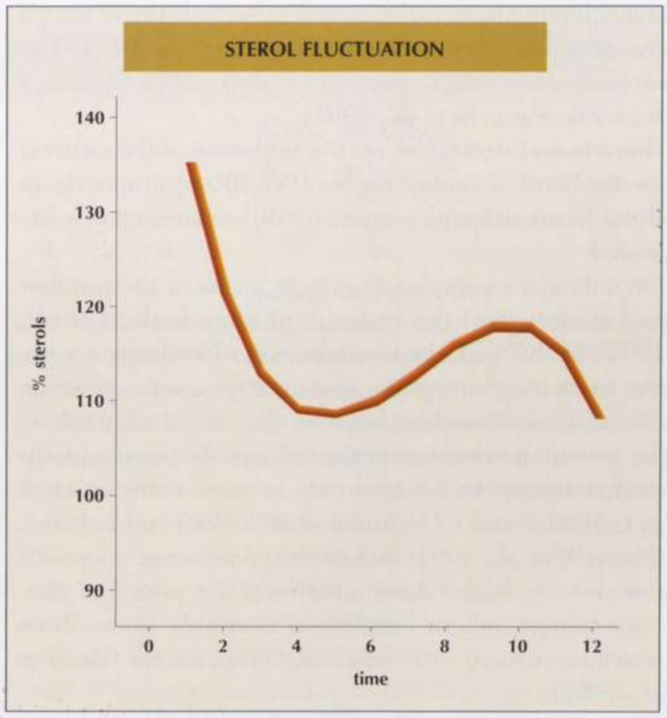


FIGURE 1. Fluctuation of sterols in time, expressed with a polynomial of the third order.

With the improvement of analytical techniques, the levels and ratios of compounds that were traditionally studied from the point of view of guaranteeing authenticity, such as aliphatic and tri-terpenic alcohols, can also be evaluated as markers to identify genetic origin (Alessandri et al., 1992b).

The cultivar has an effect on the colour of the oil, but this does not seem to be of great commercial or taxonomic value. Olives contain chlorophyll and carotenoids, even when very ripe, but there are few data referring to the fruit. Differences have been reported in the contents of the fruit of two cultivars, namely Hojiblanca and Manzanilla, the latter being less pigmented (Minguez-Mosquera and Garrido-Fernandez, 1989). References are lacking in general although oil colour has been proposed as a method for identifying and classifying virgin oils (Gutierrez and Gutierrez, 1986) and for ascertaining the area of origin (Vasconcelos, 1985), albeit with uncertain results.

The role of cultivars is particularly important with respect to the level and character of the phenols which, together with tocopherols, determine the resistance to oxidation as well as, although only in a general way, the organoleptic characteristics and preservability of the oil (Vasquez Roncero, 1978; Montedoro et al., 1979; Tiscornia et al., 1982; Cortesi and Fedeli, 1983; Cimato et al., 1991; Pannelli et al., 1991).

There is no information on the influence of the cultivar on the level of tocopherols (100-300 ppm mostly in alpha form) although significant differences can be expected.

Phenols are a complex family in terms of the number and structure of the individual chemicals (Fedeli, 1991). In the fruit, the breakdown of oleoeuropein gives rise to an indefinite group of derivatives, some of which can be used as markers because they are attributable to the genetic mechanism of the cultivar. For example, dimethyloleuropein is found only in some cultivars such as Cailletier and L11 (Amiot et al., 1986) and Leccino, (Pannelli et al., 1991) due to the presence of a specific esterase. An initial determination of the principal phenolic compounds in Frantoio is available in the three matrices «fruit,» «oil» and «vegetable water» (Baldi et al., 1992).

Flavonoid phenols and a hydrolysable-oxidisable complex fraction are found in the fruit at harvest, which give rise during the extraction processes to products which are scarcely liposoluble but are decisive for conferring specific characteristics to the oil (Montedoro and Garofalo, 1984; Montedoro, 1988, 1989; Maestro Duran, 1990; Cimato et al., 1989, 1991; Solinas, 1990; Vacca, 1990; Pannelli et al., 1991, 1992) and can potentially be used to identify the genetic matrix. The phenols are also responsible for the bitterness of oil which is only occasionally appreciated by consumers. It is not clear whether the partition of the phenols present in the oil takes place inside the cell or, as has traditionally been thought, during extraction which is the operation that is basically responsible for determining equilibrium (Cortesi and Fedeli, 1983).

Few data refer directly to the action of the individual cultivars because of overlapping interactions with the environment, time of harvest and probably the extraction systems (division and preferential extraction).

Normal oscillation for this type of compound ranges between 50 and 500 ppm, although it may be wider, and it is assumed that oils with greater amounts (in the absolute sense) have greater preservability. Nevertheless, differences in taste and preservability are not only quantitative but qualitative. A profile has been drawn up (Cimato et al., 1991) which, in addition to tyrosol and hydroxytyrosol, contains a series of 8 other compounds that have not yet been identified but have been measured in oils from 4 cultivars (Coratina, Moraiolo, Frantoio and Leccino from the same area of Tuscany). Peak 9, well represented (> 80 ppm) in Frantoio, was linked to the fruity taste, while the typical aggressiveness of Coratina is attributed to the presence, in high quantities, of compounds of peaks 4 and 7.

A comparison of oils of diverse origin has substantially confirmed these results (Solinas et al., 1992). Oil from Coratina shows a spectrum of the overall phenol complex which is quite a lot richer than in Carolea, Frantoio, Pendolino and Leccino in that order, and is linked to the strength of gustatory perception. In Umbria (Italy) it was found (Montedoro, 1983, 1989) that oils from Leccino and Frantoio have a lower phenol content that those obtained from Moraiolo, Carboncella, Nostrale, S. Felice and Dolce Agogia. In Tuscany (Cimato et al., 1991), a higher content of such compounds was reported in Coratina oils compared with Moraiolo, Frantoio, and Leccino, in that order, as well as in oils from the Monte Amiata region. Among cultivars from Sardinia, Tunda stands out for its low content when compared with Bosana and Frangivento (Vacca, 1990).

Because of the increasing chemo-taxonomical importance of this group of compounds, much more is likely to be discovered about their formation and development in the main cultivars in the Mediterranean area.

There is little information on the differences in oil aroma that are determined by the cultivar. Montedoro and Garofalo (1984) report a relatively rich aroma in Frantoio and Canino compared with Moraiolo, while other authors (Olias et al., 1980) found no clear difference between Picual and Hojiblanca.

Of the many volatile compounds that characterise oil, only a few are sensorially important; they are studied in quite large families, characterised by molecules of undefined composition. There are lists of substances known to be present in aroma and various methods have been proposed (Montedoro et al., 1972; Lercker et al., 1973), but the limited correspondence between instrumental analysis and evaluations leaves the matter unsolved and there is little information on cultivar-dependent differences.

Using the GLC headspace analysis technique (Solinas et al., 1988) on oils from various Italian cultivars (Carboncella, Caroleo, Castiglionese, Dritta, Grossa di Cassano, Frantoio, Leccino, Maurino, Nebbio) grown together and processed in the same way, 'exclusive' peaks were identified for each variety; moreover, a global evaluation of aroma intensity was provided as a varietal characteristic, taking into account that for the evaluation the authors considered that only a few compounds were relevant, especially the 2-hexenale/hexanale ratio. The same report stressed the differences that can be found between data from an experimental sample and

TABLE 6
IDENTIFIED COMPONENTS OF OLIVE OIL AROMA *

- **HYDROCARBONS**
  - Naphthalene (1)
  - Ethylnaphalene (1)
  - Dimethylnaphalene (1)
  - Acenaphtene (1)
  - n-octane (1,2)
- **ALIPHATIC ALCOHOLS**
  - Methanol (3)
  - Ethanol (3)
  - Methylpropane-1-ol (2, 3)
  - 1-pentenol (2)
  - 3-methylbuta-1-ol (2, 3)
  - cis-3-hexane-1-ol (1, 2)
  - Heptan-1-ol (2)
  - Octon-1-ol (1, 2)
  - Nonan-1-ol (1, 2)
  - 2-phenylethan-1-ol (1, 2)
- **OXYGENATED TERPENES**
  - 1.8-cineol (2)
  - Linalool (2)
  - a-terpineol (1, 2)
  - Lavandulol (1)
- **ALDEHYDES**
  - Hexanale
  - n-propanale (3)
  - 3-methylbutan-1-ale
  - 2-methylbutan-1-ale (2)
  - n-butan-1-ale (1,2)
  - trans-2-pentan-1-ale (2)
  - Penten-1=ale (prob. cis-2) (2)
  - n-hexan-1-ale (2, 1)
  - cis-2-hexen-1-ale (2)
  - trans-2-hexen-1-ale (2)
  - n-heptan-1-ale (1,2)
  - 2.4-hexadien-1-ale (2)
  - Hepten-1-ale (prob. cis-2) (2)
  - trans-2-hepten-1-ale (2)
  - Benzaldehyde (1.2)
  - n-octan-1-ale (1, 2)
  - 2.4-heptandien-1-ale (2) (2 isomers)
  - trans-2-octen-1-ale (1, 2)
  - n-nonan-1-ale (1, 2)
  - 2.4-nonadien-1-ale (2)
  - trans-2-decen-1-ale (1, 2)
  - 2.4-decadien-1-ale (2) (2 isomers)
  - trans-2-undecen-1-ale (1, 2)
- **KETONES**
  - Acetone (3)
  - 3-methylbutan-2-one (2)
  - Pentan-3-one (2, 3)
  - Hexan-2-one (2)
  - 2-methyl-2-hepten-6-one (2)
  - Octan-2-one (2)
  - Nonan-2-one (2)
  - Acetophenone (2)
- **ETHERS**
  - Methoxybenzene (1, 2)
  - 1.2-dimethoxybenzene (2)
- **FURANIC DERIVATIVES**
  - 2-propylfuran (2 isomers)
  - 2-n-pentyl-3-methyl-furan (1)
  - 2-n-propyl-dihydrofuran (1)
- **THIOPHENIC DERIVATIVES**
  - 2-isopropenylthiophene (1)
  - 2-ethyl-5-hexylthiophene
  - 2.5-diethylthiophene (1)
  - 2-ethyl-5-methyldihydrothiophene (1)
  - 2-octyl-5-methylthiophene (1)
- **ESTERS**
  - Ethylacetate (2, 3)
  - Ethylpropionate (2)
  - Methylbutyrrate (2)
  - Ethyl-2-methylpropionate (2)
  - 2-methyl-propylacetate (2)
  - Ethylbutyrrate (2)
  - Propylpropionate (2)
  - Methylpentanoate (2)
  - Ethyl-2-methylbutyrrate (2)
  - Ethyl-2-methylbutyrrate (2)
  - Ethyl-3-methylbutyrrate (2)
  - 1-propyl-2-methylpropionate (2)
  - 3-methylbutylacetate (2)
  - 2-methyl-1-propyl-2-methylpropionate (2)
  - Methylhexanoate (2)
  - cis-3-hexelynacetate (2)
  - Methyl heptanoate (1, 2)
  - Methyl octanoate (1, 2)
  - Ediethyl benzoate (1, 2)
  - Methyl salicylate (1)
  - 1-octyl acetate (2)
  - Ethyl phelacetate 92)
  - Ethyl nonanoate (1)
  - Ethyl decanoate (1)
  - Ethyl heptanoate (1)
  - Ethyl palmitate (1, 4)
  - Methyl oleate (1, 4)
  - Methyl linoleate (1, 4)

Note: *(1) Fedeli et al. (1-4); (2) Flath et al. (5); (3) Lercker et al. (6); (4) Nawar (7-8) those obtained from batches of different types and trade categories.

Fruit maturation and oil formation

The term maturation refers to a series of changes in texture, colour, sugar content, organic acids and taste which make a fruit edible, irrespective of fruit fall or harvest. Depending on how the fruit is used, this definition has been applied differently to the olive and, with regard to the production of oil, has often been interpreted as oil formation.

TABLE 7
CALCULATION OF THE INDEX OF MATURATION BY COLOUR

$$\mathbf{IM=(0{*}n0)+(1{*}n1)+(2{*}n2)+(3{*}n3)+(4{*}n4)+}$$
$$\mathbf{+(5{*}n5)+(6{*}n6)+(7{*}n7)/100}$$

n = frequency in one hundred olives **0** = green olives
1 = olives with drop in chlorophyll
2 = commencement of the change of colour
3 = almost completely coloured externally
4 = coloured externally but with little colour in the flesh
5 = superficial coloration of the flesh
6 = deep coloration of the flesh
7 = flesh completely dark

Source: National Institute for Agricultural Research, Jaen; Solinas et al., 1987.

However, it should be considered as a number of simultaneous processes, one of which is oil formation which provides the quantity, while the other phenomena and compounds help to form the technological and organoleptic characteristics of the fruit and oil. In the olive, the development of the various factors ends when the fruit falls, but it may take place over staggered periods and proceed at different speeds in different cultivars, creating maturation patterns that differ in relation to the parameters used. Maturation indices include skin and flesh colour, readiness for picking, pulp texture (for table olives), oil content or the abscission percentage (Cimato et al., 1988). The best known index is the «Colour Index» (defined as the index of maturation IM) established by researchers in Jaen (Spain) at the beginning of the seventies and given in Table 7.

In this formula, the same numbers that identify the colour class are used as multipliers, thus weighting fruit development. This index should help to define for each area when a specific moment in the development of other maturity-related characteristics has been reached (Solinas, 1990b).

«Harvesting ripeness» (or «consumption maturation», Zucconi et al., 1978) indicates the moment when the greatest quantity of oil can be harvested from the plant (expressed as the number of fruit on the plant and the oil content per fruit). This moment always comes at the time of maximum yield (maximum percentage of oil in the fresh matter) and the first natural fall. It is determined by two opposing phenomena – the accumulation of fatty matter in the drupes and the start of detachment of those fruits that have completed the cycle, which lowers the number of fruit and selectively eliminates the most developed and those with the highest oil content (Fiorino et al., 1975, 1981; Fiorino, 1977).

This phase is very short (3-4 weeks) in fast-ripening cultivars whereas in others it can last over 2 months, because the two defining phenomena tend to offset each other. On the basis of these main indices, the following agronomic classification of cultivars has been proposed (Fiorino and Nizzi Grifi, 1991):

- Premature oil formation – fast-ripening, such as Leccino;
- Premature oil formation – gradual ripening, such as Carolea;
- Late oil formation – fast-ripening (no known cases, probably non-existent)
- Late oil formation – gradual maturation, such as Coratina.

Changes in the biochemical state of the fruit during maturation can also be determined by measuring their compactness. For the best known cultivars, 4-5 weeks after the hardening of the stone, the flesh begins to soften, accompanied by a decrease in protopectins (Solinas and Marsilio, 1987). The degree of compactness and the speed of fruit fall are genetically predetermined.

In oil olives which remain on the plant for a long period of time, the fruit may be damaged during harvesting and transport to the mill, reducing keeping quality even for a brief interval. This may explain the relation between the increase in oil acidity and the harvesting period for certain cultivars and environments (Montedoro, 1984; Cimato et al., 1991). Measurements of flesh compactness in Umbria indicate a drop from slightly under 600 g/cm^2 to slightly over 200 g/cm^2 in Leccino and slightly under 300 g/cm^2 in Moraiolo, with a more premature and more accentuated fall in the former (Pannelli and Servili, 1991). No connection was found between compactness and the chemical composition of the oil.

A more complex reference which is useful not so much for identifying the best time for harvesting but for getting a better understanding of the correlation between the different phenomena occurring simultaneously inside an olive is the relation between variations in oil yield (%) and spectrophotometric absorption at wavelengths of 664 nm and 540 nm (Solinas et al., 1975). This index reveals that oil content develops in parallel with fruit development.

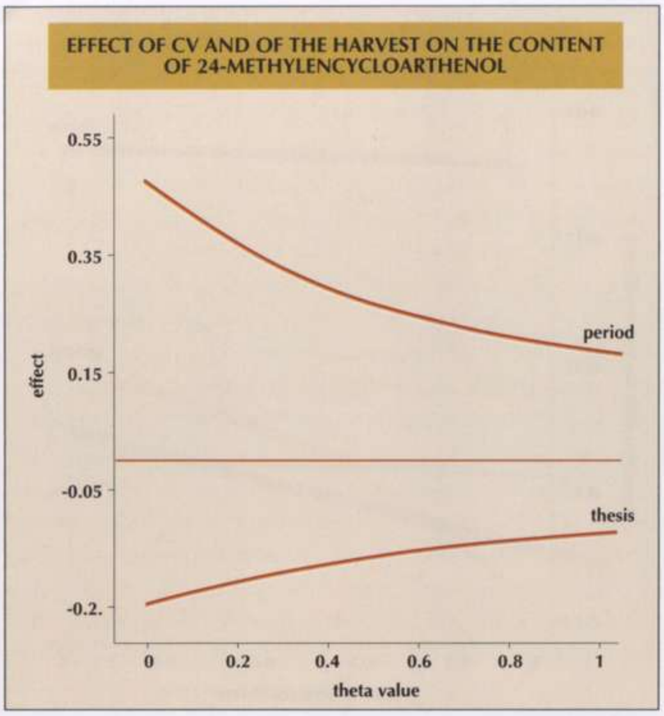


FIGURE 2. Effect of CV and of the harvest on the content of 24-methylencycloarthenol.

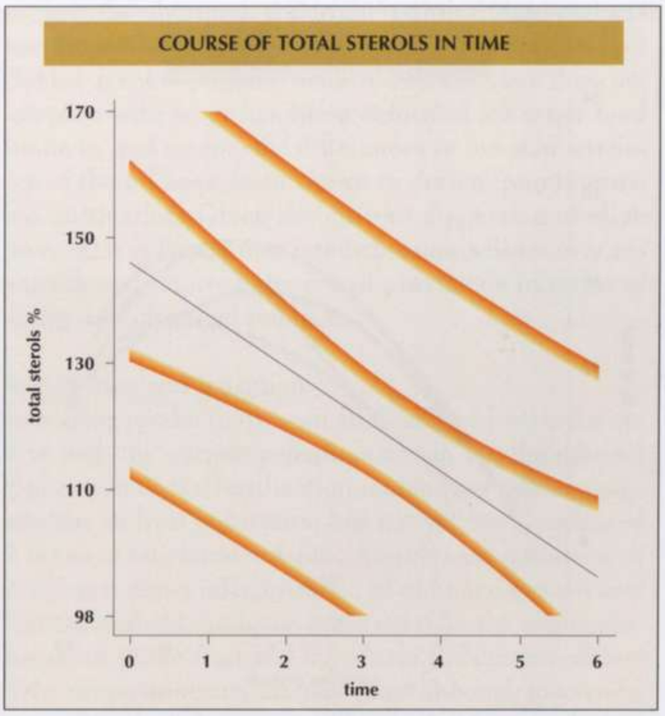


FIGURE 3. Course of total sterols in time

According to some authors, the process is so important in influencing the characteristics of an oil that it may weigh more than the genetic matrix, having effects similar to those of the extraction techniques (Montedoro, 1988).

The data given in the literature on the type and extent of the chemical and physical variations that occur in oil during maturation are not consistent. This is probably due to interactions between the genetic matrix and the environment, including cultivation techniques. Variability in the acid composition of oils from plants of the same cultivar in one collection was reported some time ago (Fiorino e Petruccioli, 1977). It has proved difficult to identify, even for 'major constituents' such as fatty acids, a certain distribution of the values (in percentages) that could help discriminate between genetically different samples (Fiorino and Nizzi Grifi, 1991), at least by analysing statistically the variations of the individual constituents for a few cultivars.

Under specific agronomic situations and over time, oleic acid seems to be relatively constant (Bocci et al., 1990), or to increase slightly with time (Modi et al., 1990b; Fiorino and Nizzi Grifi, 1991), even if this appears to run counter to the indication whereby the content (in %) of this compound diminishes in relation to latitude. Such a tendency could be due to varietal or even pest-related factors.

At least in 'cold regions', the content of two major saturated fatty acids (stearic and palmitic) decreases, especially in the latter (Modi et al., 1989b; Fiorino and Nizzi Grifi, 991), while linoleic acid content increases (Modi et al., 1990, 1992). This suggests a preferential shift in the lipid synthesis to C18:1 and C18:2, which occurs in the final phase of maturation but is concealed by the relative abundance of pre-existing lipids in the cell.

As maturation progresses, the quantity of minor compounds in the oil diminishes, albeit with different tendencies for the different chemical families.

In oils from Tuscany, of the hydrocarbons, squalene drops by about 10%, from 487 to 445 ppm in the span of one season (Modi et al., 1991). The aliphatic alcohols at times show a bell-shaped trend but with a tendency to increase, as with tri-terpenic alcohols (Modi et al., 1991, 1992). This group entails reciprocal variations with relative increases of 24-methylencycloarthenol at the expense of others in the same group (Frega and Lercker, 1986). A comparison between Frantoio and Leccino has shown that the effect of the date of harvest is greater than the action of the genetic matrix (Modi et al., 1992) (Figure 2). Conversely, the diols diminish with maturation (Fiorini and Nizzi Grifi, 1991) and their levels may vary widely (constant cultivar, environment) at the beginning of the harvesting season, while they

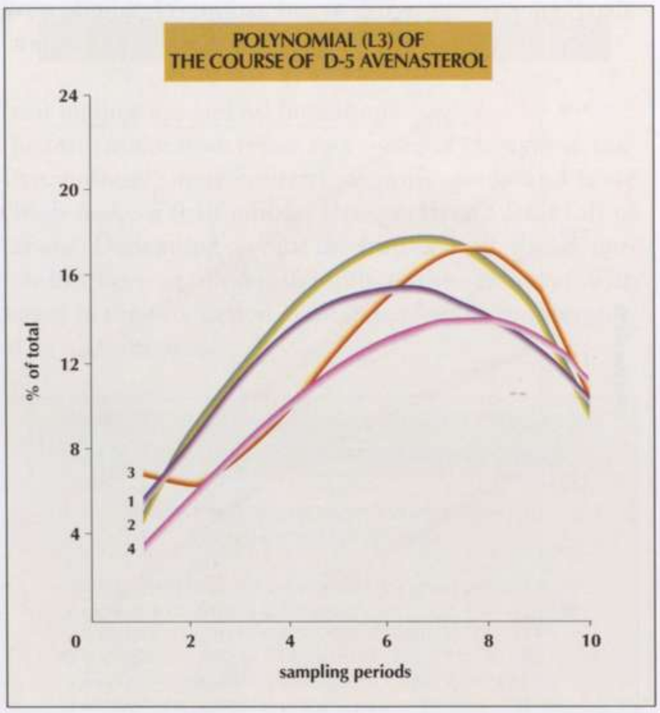


FIGURE 4. Polynomial (3rd order) (L3) of the course of d-5 avenasterol.

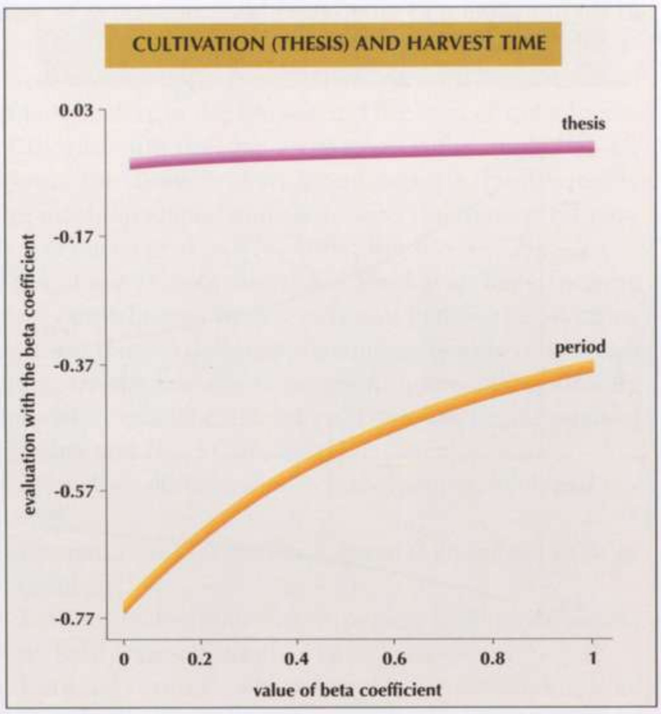


FIGURE 5. Weight of cultivar (thesis) and harvest time on sterol levels.

tend to concentrate during the middle of the period when the olives are riper.

The development of tocopherols in the fruit and the influence on them of the genetic matrix is still unknown. In Tuscan oils they were found to decrease slowly, and content was 25% lower two months after the start of harvest (Cimato et al., 1991).

Pigment content also decreases. The reduction in «Frantoio» oils can be measured by spectrophotometric evaluation of the chlorophyll and (beta)carotene (Modi et al., 1992). In general, cultivars that ripen slowly maintain the green colour in the oil longer than those that ripen fast, even when harvested fairly late. The change and fading of oil colour actually depend on the speed at which the fruit chromoplast falls, which may contain chlorophyll concealed by other newly-formed and non-liposoluble pigments (Fiorino and Nizzi Grifi, 1991). The extraction and separation technology may affect the quantity of liposoluble pigments passing in the various fractions – oil/water/pomace. However, further study is required into their content in the various parts of the fruit and their dispersion into the different fractions.

Total sterol content in oils varies (Camera et al., 1975; Modi et al., 1990) and, apart from its wavy behaviour (Figure 1), is known to decrease after harvesting in monovarietal oils (Figure 3). Of particular interest is the pattern of the contents of (delta)5 avenasterol (Figure 4) (Fiorino and Nizzi Grifi, 1991) which first increases (in %) at the expense of (beta) sitosterol and then drops. According to some researchers (Camera et al., 1975), this compound is said to reach its highest value (in %) corresponding to maximum oil formation.

For these compounds as well, the effect of the date of harvest may exceed that of the genetic matrix (Figure 5) in certain olive-growing areas.

The group which undergoes the greatest transformation is that of the minor polar compounds.

There is no general agreement as to the dynamics of formation and determination of levels of the various representatives of this family during maturation, nor is it possible to suggest a suitable hypothesis to reconcile the different opinions without proper comparison of the oil obtention methodology and data on the phenological phase of the fruit, year and cultivar. According to most authors, total phenols expressed as caffeic acid, diminish during ripening (Cimato et al., 1988; Modi et al., 1991), while others claim that the values fluctuate or even increase, at least during the maturation period examined and depending on the extraction system used, with a specific increase of the complex fraction which contains hydroxytyrosol (Pannelli et al., 1991), while the complex hydrolysable fraction which contains tyrosol drops, at least in the Leccino and Moraiolo cultivars in Umbria. The tyrosol fraction is probably derived from the seed (Maestro Duran, 1989) and is

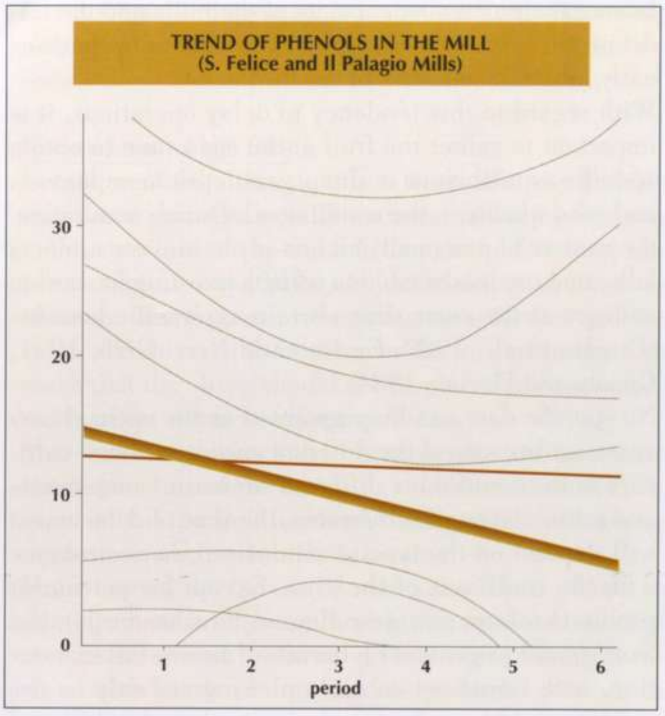


FIGURE 6. Trend of phenols in the mill.

therefore of little importance in the composition of the phenol spectrum.

The decrease in total phenols appears to be relatively constant in every cultivar, but may speed up under favourable ripening conditions (Modi et al., 1990) (Figure 6). The time of harvest does not only diminish total quality, but may also affect the relative distribution of the different phenols (Cimato et al., 1991).

It is generally accepted that the aroma of the oil is influenced little by the original aromas of the fruit. According to certain researchers (Montedoro and Garofalo, 1984), there is also a correlation between maturation and the levels of aldehydes in the oil, which are said to increase with oil formation and then start to drop during the real maturation of the fruit, behaving in a manner contrary to the alcohols. Any attempt to relate the content of certain components of aroma with the colour index (IM) shows that the products of greatest interest, because of the positive attributes they give the oil, follow a bell-shaped trend with the peak at the start of ripening (IM between 2 and 4) (Solinas et al., 1987).

TECHNICAL CHOICES

Agronomic practices

Every element of cultural care brings improvements to the productive conditions of the plant so, if a good product is to be obtained, the 'right' cultural care and extraction methods must be applied.

The low level of progress achieved for the olive does not compare with what has been achieved for other food products, and no specific differences in the characteristics of the oil have been shown to derive from intensified cultivation. Given the current dispersion of olive growing, it is hoped that intensification will recover resources and improve the use of provisions in terms of energy and chemical products.

Fertilisation and irrigation

Increasing productivity is an attainable objective for the olive with the current genetic material, but the rational application of the fertilisation techniques now in common use in fruit cultivation has not yet been evaluated in terms of oil characteristics. An increase in the use of fertilisers, especially nitrates, to enhance growth and fruit set probably induces some delay in the accumulation of oil in the fruit and influences the characteristics of the drupe as occurs in «on» years although to a lesser extent, precisely because of the vegetative support provided by the fertilisers.

It is generally considered that the traits of the oil cannot be easily influenced. Only a slight shift is reported in the equilibrium between the different fatty acids in relation to nitrogen-based fertilisers (Tombesi, 1992).

Irrigation also exerts a strong influence on vegetation, yield and fruit growth, which may in turn influence the resulting oil. With regard to colour, irrigation increases (or preserves) chlorophyll (Tombesi, 1992). The proportions between the fatty acids are slightly altered (Dettori and Russo, 1992), although this category of compounds is relatively stable (Rotundo et al., 1992). The phenol and sterol levels are reduced (Stefanoudati and Kouzaftakis, 1992) by irrigation, while the components of oil fragrance and freshness increase with irrigation.

Other practices

The role of tree stance and pruning operations has not yet been defined although quantity parameters change. Because production has remained at low levels, it has not yet been possible to explore the consequences of intensified production on oil characteristics.

Recent studies (Famiani et al., 1992) seem to show that the tree load has a negative effect not only on oil yield, which is only to be expected, but also on phenol content and resistance to oxidation. The effect of the age of the plant (Rugini and Fedeli, 1990) has not been defined because of a lack of appropriate comparisons. For many cultivars, the data available pertain only to new plantations or rejuvenated plants.

Pest control

Of the many pests of the olive, it is the olive fruit fly (*Dacus oleae*), which is endemic in traditional olive-growing regions, that has caused the most damage. This insect attacks the fruit when it has already grown and does so for a long span of time. As a result, part or all of the production can be lost, or the oil from the infested olives, often harvested from the ground, may be rendered inedible. The extent of the economically tolerable damage is a matter of debate and is difficult to measure because a relation has to be established between the period of infestation, the date of the first major attack, prevailing temperatures, the duration of harvesting, storage of fruit before pressing and the characteristics of the product.

The presence of 10-15% of fruit with fertile punctures substantially changes the organoleptic characteristics of the oil, in addition to the instrumental readings for acidity and peroxides. Serious infestation levels increase the difficulty of harvesting, transport, and preserving the fruit, which degenerates rapidly. In massive attacks, the acid composition itself is modified (Benfatto, 1990), as saturated fatty acids seem to increase (Parlati et al., 1992) and the oleic acid content decreases. This affirmation, shared by researchers from various countries, gives rise to reservations about analyses carried out in the past on commercial consignments pertaining to the acid composition of oils from regions characterised by mild winters, with serious attacks by flies.

Concern to improve oil quality has led to campaigns to fight this pest, the presence of which downgrades oils even if the infestation is contained (Montedoro et al., 1985; Cirio and di Ciocco, 1989). Damage caused by the fly is twofold: not only does it damage the pulp itself but the damage fosters the presence of fungi, in particular a Sphaeropsis, which causes intense, harmful enzymatic activity.

Harvesting period and techniques

Once they have been detached from the plant, the biochemical development of the fruits comes to an end, so the choice of the time of harvest represents the most decisive decision in determining product quality (Montedoro, 1988). Research on mechanical harvesting has shown that the characteristics of the oil change with time (Fiorino, 1977) and attempts have been made to find out which factors cause the changes (Fiorino, 1977; 1981) in order to define them chemically.

The harvest season normally lasts 2 to 4 months, depending on the year and the region. Despite technological developments, it is conditioned by the availability of labour, the processing capacity of the mills and the traditional resistance of farmers to starting operations early, when the oil yield of the fruit is low.

With regard to this tendency to delay operations, it is important to gather the fruit at the right time to obtain specific equilibrium in the organoleptic components and good quality in the resulting oil. During maturation, the content of practically all non-glyceridic constituents falls, making it advisable to bring harvesting forward to achieve at the same time certain agronomic benefits (Cimato et al., 1988; Fiorino and Nizzi Grifi, 1991; Cimato and Fiorino, 1984).

No specific date can be pinpointed as the optimal harvest time because of the different speeds at which cultivars mature and their different aromatic components and initial flavour. Furthermore, the time of detachment will depend on the type of oil desired, in accordance with the traditions of the area. Except for particular products (clear, sweet or almond-flavoured oils), the fruit should in general be harvested before full maturation, with limits set on early picking not only by the smaller yield but also in relation to the tolerability of the phenolic load of each cultivar. To identify the links between different parameters, agronomic harvesting indices (HI) have been drawn up (Modi et al., 1990) which establish a relation between the oil yield of the drupes and the phenol content, attempting to reconcile production requirements with organoleptic characteristics.

It should be pointed out that, under ordinary conditions, the optimal moment in quantitative and qualitative terms is when premature drop is between 15 and 20%, remembering that «earlier periods are more reliable than later periods» (Tombesi, 1992).

The harvest can be carried out manually, mechanically or with auxiliary instruments (Fiorino, 1973). Because of the high cost and limited availability of labour, hopes are focused on mechanical harvesting which is slow in gaining currency because of the low productive efficiency of olives (at times less than 300 grams of product/m3 of tree canopy in intensive orchards) and because of the low percentage of fruit detachment due to the characteristics of olives, which have a high resistance/weight ratio. This ratio diminishes with maturation – very fast in cultivars with rapid maturation and slower in those that mature gradually. Premature drop, however, is controlled.

Various substances are used to enhance the efficiency of shakers, including hormones, although doubts as to their suitability have been expressed (Fiorino, 1981). Apart from damage to vegetation, variable responses and the different speed of response of the fruits at different stages of development, some such substances are very effective and economical but may affect oil characteristics.

Preservation of the fruit

Detachment from the plant is a traumatic event which may cause damage, usually underestimated by farmers, to the structure of the fruit. Although the fruit may appear intact, it may still be subject to degeneration phenomena. The tissues of the pulp are softened and the cells, which are rich in oil, may be torn or bruised so much that the olives should not be placed in bags, especially under warm weather conditions.

Preservation reduces the organoleptic and aromatic characteristics of the resulting oil (Montedoro, 1992), especially if the fruit has been damaged by the harvesting techniques used (such as beating).

In any event, the harvested olives should be placed in thin layers on structures allowing proper ventilation and processed, at most, within 3-4 days after picking in regions with harsh winters, and over shorter periods as maturation progresses and/or as the temperature rises, to impede fermentation.

Extraction systems

There is extensive literature on the various systems for obtaining oil (Cucurachi, 1975) and the effects of every system on oil acidity are well known. Studies have also been carried out into the influence of the various extraction systems on other chemical constituents and on the specific organoleptic characteristics of virgin oil (Solinas et al., 1975), considered in terms of compatibility with trade standards and pollution regulations. After making the organoleptic assessment, such studies took into consideration other characteristics apart from the yield and possible structural defects of virgin oils.

The various systems can be described very simply in terms of crushing the fruit and separating the oil from the remaining fraction of the original fruit. Beating or mixing of the pastes is now commonly carried out between these two phases – to encourage the coalescence of the oil drops. Enzymatic reactions are activated in this phase, giving rise to oxidising processes; the ratios between the various minor compounds in the oil are modified, the aldehydes increase and the total phenol load decreases (Montedoro, 1992; Servili et al., 1992).

Crushing can be carried out with either stone or metal crushers.

Stone was the only material available for this operation until the end of the 19th century, and oil production is virtually the last agricultural operation to be still using such a traditional process. Metal crushers are basically of two types – hammers and cylinders, with various technical devices applied to improve efficiency.

There are a few differences between the two groups:

a) Granite millstones also crush the olive pit to some extent and probably have some effect on the skin. They crush the tissues of the mesocarp without raising the temperature and the paste is suitable for pressing without any particular technical devices being required.

b) The use of hammer crushers of various types, which are the most widely-used type of metal crushers, gives a more homogenised paste with greater dispersion of the oil in the colloids but with a rise in temperature due to the impact and friction on the paste. This phenomenon varies depending on the devices used. The use of crushers is faster and makes movement of the paste easier. The instruments are also easy to clean.

Separation of the oil can occur in three ways:

1) Separation of the pomace and oily must by pressure, followed by separation of the vegetable water and oil. This is the traditional system which today uses centrifugation for the second phase.

2) Separation of the oil from the paste by virtue of different surface tensions (percolation).

3) Separation of the oil from the paste, sometimes mixed with water, by means of centrifugation followed by separation of the vegetable water and the pomace.

System 2 exhausts only part of the paste. The efficiency (or speed) of extraction depends inversely on oil content. In order for the system to be economical, therefore, action must be suspended when 60/70% of the oil has been recovered. The remainder should be extracted with system 3. The oils obtained are quite similar in terms of the composition in fatty acids, sterols and alcohols, which are slightly diversified by rheological indices (only the peroxide value is affected), but they taste different (Fiorino).

Various combinations of the crushing and separation systems are possible, as well as other, less common operations for the preparation of the paste (di Giovacchino, 1990), such as stone removal. There is certainly an interaction between the genetic matrix, time of harvest and extraction system which characterises the product. Research studies aimed at illustrating the action of the milling system by comparative means are few. The roller mill system makes it possible to obtain oils which are richer in volatile substances and phenols and are less bitter and pungent (Angerosa and Solinas, 1990); the speed of crushing with hammers modifies certain organoleptic characteristics of the oil (Solinas, 1990), and changes have been reported in the stability and in the content of natural anti-oxidants when operating with a continuous cycle (di Giovacchino and Solinas, 1992). Particular attention should be focused on those characteristics of the oil which can be influenced by the separation process, because the physical principles of separation are very different as are the balances established between the various phases during extraction.

Oil obtained by quasi-traditional methods (in which centrifugation is generally used), which is taken as the 'point of reference', shows equilibrium amongst the minor polar constituents in the various phases as defined by the separation speed and by the oil and vegetable water separation. By adapting the three different methods of extraction, it is possible to alter the organoleptic and structural characteristics of the product, such as resistance to oxidation, rancidity and preservability (Cortesi and Fedeli, 1983; Pannelli et al., 1991).

The various techniques, but especially poor techniques, might produce different hydrolysis indices for minor polar compounds (Fedeli, 1991), and the differences between such indices may be used to evaluate the post-harvest operations.

The 'traditional' combination of milling, pressing and centrifugation (a-1) recovers the largest quantity of oil, because the paste can be treated repeatedly and because high pressures can be applied. But it is a relatively slow (discontinuous) system that is not infallible and that requires many skilled operators.

The hammer mill and centrifugation combination (b-3) is fast, fully mechanisable and easy to manage, even though high temperatures may be involved which are not advisable from the quality point of view.

If the olives are processed fresh, no substantial differences are noted amongst the different systems in acid composition, in the complexes of unsaponifiable matter and in free acidity. System b–3) occasionally gives rise to a more bitter taste (Angerosa and Solinas, 1990; Solinas, 1990), while system b–2) leads to the formation of oils which are less intensely coloured and more fragrant than those of system b–3). Comparison between systems a–1) and b–3) using 96 representative samples from one harvesting season from a specific territory (Tuscany) has shown that there are small differences in the chemical analysis of oils (in favour of the traditional system); with regard to the analysis of organoleptic characteristics, nearly 70% were good to very good with system b–3), while this percentage dropped to about 20% for combination a–1) (Cimato et al., 1991) due to the rise in olfactory and gustatory defects.

The sector is developing fast and new applications, such as the addition of extraction aids or enzymes to the paste to accelerate and improve the efficiency of extraction systems, appear to be capable of substantially modifying (Montedoro, 1992) a method which has remained unquestioned for more than 2,000 years.

USE OF PHYSICO-CHEMICAL ANALYSES TO IDENTIFY AND CALCULATE CLASSIFICATION MODELS

Classification models and the statistical methods linked to them can be extremely valuable instruments for dealing with problems concerning the region of origin and product quality (Alessandri et al., 1991, 1992) and the taxonomy of the cultivars or clones (Casini et al., 1992) because, if duly calibrated, validated and tested, they allow not only an exploratory but also a predictive approach.

A good model makes it possible to deal operatively with problems of recognition, attribution and decision. It is therefore an instrument that goes beyond the cognitive aspect of the matter in question.

Many expert systems are based on classification models; see the works of Aparicio et al. (1987), Derde et al. (1987), Aparicio (1988), Aparicio et al. (1988), Aparicio et al. (1990), Aparicio (1991), Aparicio et al. (1991a), Aparicio et al. (1991b).

The cognitive moment (Armanino et al., 1989, Alessandri, 1991) continues to be indispensable nonetheless for developing a classification model, and many methods help to do this, a few of which will be briefly described below.

The exploratory and descriptive phase is particularly important because the very possibility of such a model functioning is based on the certainty of the proper knowledge and attribution of a set of learning observations which constitute what we might call the «knowledge base» – a term borrowed from the PROLOG language.

If we take a set of oil samples on which a series of chemical analyses have been conducted, and we know that they come from two or more production areas, we can refer to them as «observations» (or «objects»). The area of production is called a «classification variable (or criterion)» and is usually qualitative. Every chemical determination, however, generates an «analysis variable» which is usually quantitative and is expressed in numeric terms. The set of observations is called the «statistical set.»

If we take a system of Cartesian axes, where the values of a corresponding analysis variable refer to each axis then, for each observation, we can assign a point in a space of a number of dimensions equal to the number of analysis variables considered.

The set of points which thus represent the corresponding observations is called the «scatter.» The limit of visualising more than three variables in graph form is self-evident, as is the need to identify other ways for studying n-dimensional phenomena, where $n > 3$: the subject is covered further below (reduction of dimensionality).

It should be stressed that we are dealing with «multivariate» analysis whenever more than one variable (and thus more than one dimension) is considered concurrently, and that it is possible to represent (in a scatter diagram) the various modalities of one classification variable, using colours or symbols instead of dots. This makes it possible to «visualise» any clusters of observations belonging to the same class, and just like the scatter, independently of any classification criterion known a priori, facilitates the exploration of the observations under consideration (variability, course, correlations, clusters, etc.).

PRINCIPAL COMPONENT ANALYSIS

There are various calculation systems available which can guide a researcher when classifying observations. In this field of application, the simplest method is Principal Component Analysis (PCA), a very flexible technique with numerous applications.

This method makes it possible to explore relations between variables, simplifies the description and representation of multi-dimensional phenomena, and can be used to isolate useful information from «noise» inside a group of variables where no subdivision is made between the dependent and independent.

The primary purpose of PCA is to obtain a small group of linear combinations (Principal Components) from a set of initial (quantitative) variables, without any appreciable loss of useful information, but rather with a reduction of «background noise» and identification of the «outliers» (Armanino et al., 1989).

Cluster analyses can then be conducted on the principal components to determine regression models, calculate classification models and find relations and links between the original variables, taken one by one or in groups, and the components themselves.

The principal components owe their name to the characteristic of being able to describe, in an optimal manner, the variability of the set under observation: the first principal component extracted can be thought of as the straight line best suited for the scatter of observations in the n-dimensional space of the analysis variables under consideration; the second as the best suited for the residual variability, and so on.

CLUSTER ANALYSIS

The purpose of cluster analysis is to:

- Establish whether it is possible to recognise clusters in a certain set of observations;
- Identify said clusters;
- Describe them statistically.

The applications include the work of Ferreira (1985) who singled out 8 different clusters for 8 production areas in Portugal using PCA to analyse acidity, peroxides, UV spectrometry, the Bellier index, fatty acids, fatty acids in the 2-position and sterols.

Tsimidou et al. (1987) applied PCA to the analysis of fatty acids and triglycerides (which seem to be more indicative) to identify clusters according to the place of production of Greek oils.

Armanino et al. (1989) applied cluster analysis (average linkage method) to the first 5 principal components, extracted from a matrix of data obtained from chemical analysis of oils from Tuscany, to divide the region into zones on the basis of the characteristics of the oils, with good approximation results.

Zupan and Massart (1989) used the «three distance method» in their analyses of the acid fraction. Alessandri (1990) on the other hand, applied various cluster analysis techniques on original and/or processed variables, to define sub-groups of variables, inside Tuscany, that could identify homogeneous zones of production, taking into account the period of harvest of the olives, and especially the «performance» of the proposed models beyond annual variability. Aparicio et al. (1991a) used the Average Distance Method to group together 97 oils harvested in 1988 in the province of Jaen in Spain according to their place of origin.

DISCRIMINANT ANALYSIS

Discriminant analysis deals with sets of observations where:

- Groups or classes are known (e.g. production region, cultivar, etc.);
- One or more quantitative variables are defined (for example, chemical analysis, carpometric readings, etc.).

This definition comprises discriminant analysis geared to the production of classification models (classificatory), canonical discriminant analysis and step-wise discriminant analysis, the latter being geared to reducing the dimensionality of the models.

For specific treatment of the subject, see Hand (1981), Lachenbruch et al. (1968); Lachenbruch (1975); Seber (1984); for applications linked to olive growing, see Frank et al. (1989).

Classification models

Classificatory discriminant analysis (called simply «discriminant analysis») allows the development of a mathematical rule based on the quantitative variables taken into consideration, which can be used to attribute an observation to one of the classes, with a minimal possibility of error. It provides the instruments for classifying observations of unknown or dubious origins, on the basis of what has been learnt from observations of a certain origin, and thus makes it possible to construct operational classification models.

It is divided into numerous parametric and non-parametric methods. It is possible to determine linear discriminant functions (LDA, or Linear Discriminant Analysis), or quadratic discriminant functions (QDA, or Quadratic Discriminant Analysis). With QDA, no assumptions as to the homogeneity of the co-variance matrices within classes are required.

With non-parametric discriminant analysis methods (Hand, 1992), no assumptions about normal distribution within classes are required.

The technique of submitting to LDA or to QDA variables transformed by rank, as proposed by Conover and Iman (1980) and adopted by Seber (1984) and applied on the chemical analysis of oil samples from Tuscany by Alessandri (1991), Alessandri et al. (1992), Cimato et al. (1992), acts as a bridge between parametric and non-parametric methods.

Various methods other than discriminant analysis have been tried out to construct oil classification models; for example, Derde et al. (1982) used SIMCA to classify Italian oils; Frank and Lanteri (1989) compared LDA, SIMCA and CART; Aparicio et al. (1987, 1988, 1990, 1991a; 1991b), and Derde (1987), however, are working on expert systems.

Canonical variables and CDA

The objectives of Canonical Discriminant Analysis (CDA) are as follows:

- To determine the linear combinations (defined as canonical variables) of the quantitative variables under consideration, which best summarise variability between the classes;
- To select a set of a few canonical variables which can advantageously replace the many (in comparison with the canonical) original quantitative variables, for the classification of data;
- To provide an aid for the comprehension and representation (including graph form) of the phenomenon under consideration.

The canonical variables have the characteristic of being non-correlated with each other and, like the principal components, they are linear combinations of the original variables.

The interpretation and utilisation of the canonical variables are discussed by Klecka (1980), and Seber (1984); for applications in olive-growing, see Sarrion Martinez et al. (1986), Aparicio et al. (1987, 1988, 1990), Alessandri et al. (1992).

Dimensionality reduction

There are many techniques that can be used to reduce the dimensionality of a phenomenon for the purpose of making it easier to understand and to represent.

These include step-wise discriminant analysis and the use of some of the results of the PCA and/or CDA.

The purpose of step-wise discriminant analysis is to:

- determine the most important variables for correct classification of the observations;
- eliminate from the model those variables which are of little use for this purpose.

Step-wise discriminant analysis pursues this objective directly with the step-wise elimination and/or introduction of one variable at a time into the model, by means of various possible evaluation criteria (Aparicio et al., 1988; Alessandri, 1991; Alessandri et al., 1991).

PCA and CDA are used to select a sub-set of Principal Components or Canonical Variables that are considered suitable for describing in a satisfactory manner the set under consideration. Then the original variables are gradually included into the model, if strongly linked to the principal components or to the canonical variables selected. The model may also be constructed on the latter.

Cross validation of the models and evaluation of the discriminatory power

Cross-validation (the «leaving one out» method) is a process which consists of classifying every observation (of a set of n elements), on the basis of the discriminating criterion drawn from the other (n-1) observations; it then requires that this function be recalculated as many times as there are observations.

«Leaving-one-out» cross-validation prevents artificially low attribution errors which are not a good estimate of the real discriminating power of the model. It is applied by Sarrion Martinez et al. (1986), Alessandri (1991), Alessandri et al. (1991, 1992). There are also «leaving-more-out» methods (Leardi and Paganuzzi, 1987) in which the observations left out constitute a random sample of the set considered (n>1). For more detailed discussion on the estimation of the predictive power of models and of cross-validation models, see Lachenbruch and Mickey, 1968; Lachenbruch, 1975; Seber, 1984.

It does not seem possible to take into consideration, not even for purely exploratory purposes, non-validated models (Lachenbruch et al., 1968), because of the extremely probable collapse of their discriminatory effectiveness when tested on observations other than those on which the model itself was calculated.

The cross-validation method can be applied also to the calculation of principal components (Alberghina G. et al., 1991) and regression models.

It is important to stress that the discriminatory effectiveness of a model should not be evaluated only on the basis of the total attribution errors, with a merely quantitative criterion, even if it is based on a suitable cross-validation. In many cases, it may be more important to evaluate the quality of the errors themselves thereby endowing the model with a risk matrix.

This entails giving different weight to different errors, or giving preference to models oriented at not making a certain type of error, if necessary to the detriment of precision on other attributions that are considered less serious if erroneous (Alessandri 1991; Alessandri et al., 1992).

For example, in models used to obtain an early diagnosis it may be tolerable to classify a healthy subject as being ill (subsequent checks will correct the error), but classifying a subject at risk as healthy must be avoided. In this regard, it might prove useful to endow the models with minimal attribution probability thresholds. An observation should be attributed to a certain class only if the attribution probability exceeds the preselected threshold; otherwise, it should not be classified at all. In this way, «weak» attributions are detected (Alessandri, 1991; Alessandri et al., 1992), and it is possible to evaluate the «performance» of the model with respect to the progressive increases in the said threshold.

Another evaluation parameter is provided by the dispersion of the attribution error per class. The aim is generally to minimise this by means of homogeneous distribution of the erroneous attributions among the classes (or between a few of them if a risk matrix is adopted).

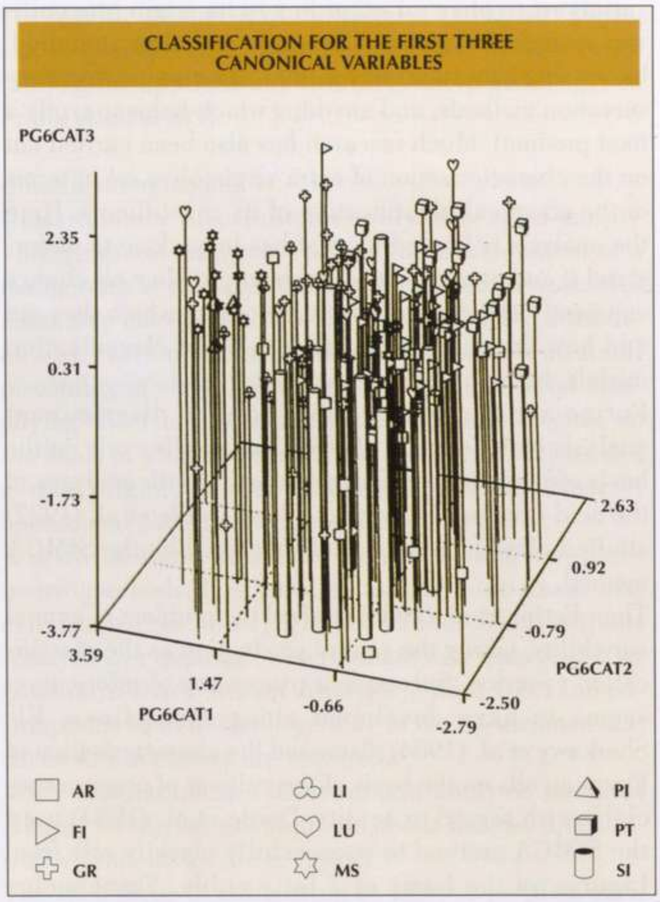
Applications

The use of various mathematical and statistical systems has given rise to a considerable amount of research, among which it is important to single out studies on variations in olive oil according to its origin (the cultivar, area of production, agronomic techniques applied, harvesting times and techniques, processing and conservation methods, and anything which helps to typify a food product). Much research has also been carried out on the characterisation of extra virgin olive oil in terms of the chemical identification of its constituents. Here the analysis is limited to what has been done to understand if any constituents of extra virgin olive oil change constantly and regularly with the origin, which they are and how they change in order to build classification models, based on information of this kind.

Forina and Tiscornia (1982) applied discriminant analysis techniques to classify Italian olive oils on the basis of their region of origin, starting with analyses of the acid fraction. In the same year, Derde et al. (1982) studied classification models obtained by the SIMCA method.

Then Forina et al. (1983) studied the problem of annual variability, taking the year of production as the classification criterion. Subsequent processing of information seems to have developed along these lines. El-Sharkawy et al. (1984) discussed the characterisation of Egyptian oils on the basis of the cultivar of origin, especially with regard to acidity. Derde et al. (1984) used the SIMCA method to successfully classify oils from Liguria on the basis of 7 fatty acids. Vasconcelos (1985), although concluding that it does not seem possible, tried to classify Portuguese oils on the basis of area of production, by using colour. Not all experimental works are 'homogeneous'. Sarrion et al. (1986) selected palmitic and palmitoleic acids for their discriminatory power, while Forcadell et al. (1988) proposed three models in which the greatest importance for the correct attribution of observations was given to the arachic, linoleic, oleic, stearic and linolenic acids.

Lopez Sabater et al. (1986), using discriminant analysis on the acid fraction to determine the original cultivar of 51 samples, referred to palmitoleic, stearic, linoleic, and linolenic acid as being mainly responsible for the separation of the observations. Derde and Massart (1986) applied the VNEQ method instead of the SIMCA method, to classify oils from 9 Italian regions, on the basis of the acid fraction. Aparicio et al. (1987) tackled the problem of oil classification by implementing an expert system (called SEXIA) in order to define the place of origin and cultivar, starting from a pool of chemical analyses comprising acidity, UV and visible spectrophotometry, sterols, fatty acids, alcohols and phytol, tri-terpenic alcohols. The system is based on rules which are themselves based on various methods of classificatory and canonical discriminant analysis and on



CLASSIFICATION FOR THE FIRST THREE CANONICAL VARIABLES

FIGURE 7. Canonical discriminant analysis on the standardised variables ranked by the Bloom method.

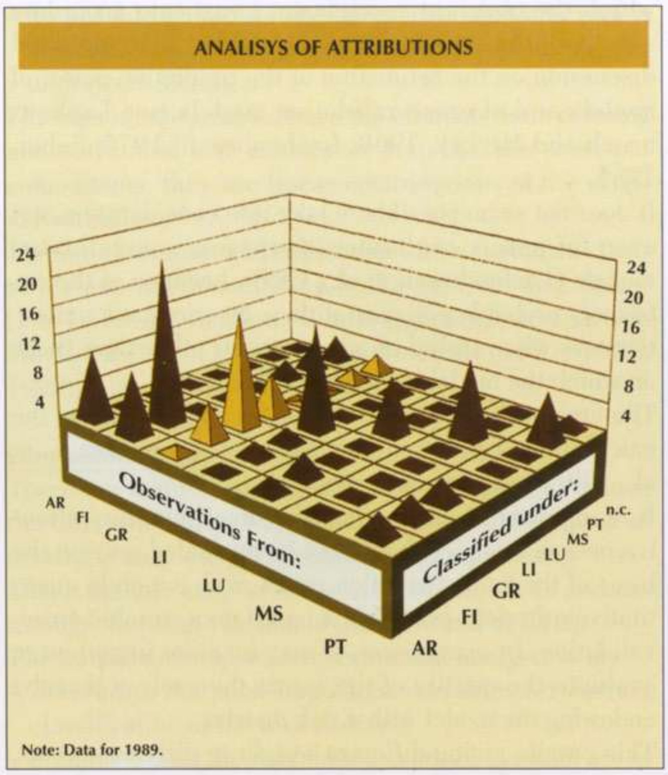
step-wise variable selection techniques (Aparicio et al., 1988, 1990). The system is also compared with the BMDP package as regards the selection of variables which are of importance for the classification of the cultivar (Aparicio, 1988).

Derde et al. (1987) also worked on expert systems for the classification of oils and the SEXIA method is still being studied and applied by Aparicio et al. (1991 a and b).

Leardi and Paganuzzi (1987) distinguish between Greek, Spanish and Tunisian oils by using the sterol fraction and acidity. Finally, Graciani (1987) tackles the problem of the characterisation of Spanish oils on the basis of the cultivar and the area of origin by means of triacylglycerol analysis.

Alberghina et al. (1991) conducted a geographical classification of Sicilian oils, based on the sterol and acid fractions.

Alessandri (1991), Cimato et al. (1991, 1992) took 77 variables from chemical analyses (acidity, peroxides, UV and visible spectrophotometry), alcohols and phytol, fatty acids, sterols and squalene, minor polar compounds, tocopherols) from 270 samples of extra virgin oils produced in Tuscany in the 1988-89 and 1989-90 seasons, to investigate whether it is possible to develop cross-validated models which are stable with respect to annual variability and capable of classifying oils correctly on the basis of place of origin or harvesting time. They also took into account, in a differentiated manner, the various possible errors and a minimum attribution threshold, and proposed selection criteria applied with step-wise methods for the formulation of reduced dimensionality models of chemically homogeneous groups of variables.



ANALISYS OF ATTRIBUTIONS

Note: Data for 1989.

FIGURE 8. Cross-validated discriminant analysis. Kernel method on 10 variables (fatty acids).

Alessandri et al. (1991) formulated a classification model for Tuscan oils based on variables derived from the analysis of minor polar constituents (normalised and standardised by ranks) and on QDA. The model is oriented toward the recognition of samples characterised by the fact that they came from prematurely harvested fruits. Alessandri et al. (1992) then produced a cross-validated classification model. Figure 7 shows the scatter diagram of observations in the space of the first three canonical variables extracted from the variables standardised by ranks. The matrix is given in Figure 7 and Figure 8 shows the graph of the attributions.

This model (with a minimum attribution threshold of 0.45) used the kernel method to identify the area of production of Tuscan oils, based on analyses of the acid fraction. The model turned out to be stable in both of the years considered and was of interest when tested with observations excluded from its construction.

Ferreiro and Aparicio (1992) studied the chemical composition of Andalusian oils and formulated models to classify samples according to the altitude of the area of origin. The models were successfully compared with samples from other years (1989) and different areas.

PROSPECTS

Classification models are not yet widely used because the methodologies used to construct them are still open to debate and their applicability to many contexts has not yet been established. The calculation of the models, whether descriptive or predictive, may include variables of different types (physical, physico-chemical, chemical, organoleptic, etc.) and may therefore give rise to many difficulties.

It is necessary to determine what facts are known with certainty, giving the sources of variations and their effects on the characteristics to be examined.

It seems indispensable that this type of instrument must go side by side with research into the biological, physiological and biochemical aspects and mechanisms which are responsible for variability related to area, cultivar, agronomic practices and extraction technologies.

This variability can be brought to light by the models but not interpreted.

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Chapter 6

PLANT PROTECTION. DEVELOPMENT OF METHODOLOGIES AND THE PROTECTION OF PRODUCTION AND THE ENVIRONMENT

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PLANT PROTECTION

DEVELOPMENT OF METHODOLOGIES AND THE PROTECTION OF PRODUCTION AND THE ENVIRONMENT

ANTONELLO CROVETTI

Unlike other agricultural ecosystems, the olive orchard appears to be fairly stable because of the remarkably complex intra- and inter-species relations in the populations of insects inherent to olive cultivation, owing especially to the olive's long growing period. Two examples are the main phytophagous insect, the olive fruit fly *Bactrocera oleae* (Gmelin), whose natural enemies include certain Hymenoptera species which likewise live on other phytophagous insects inherent to the olive or other plants growing spontaneously in the vicinity of the orchard, and the olive moth *Prays oleae* (Bernard) whose natural enemies include a complex of 40 other entomophagous species. Among these, the predator *Xanthandrus comtus* (Harr.) (*Diptera Syrphidae*) can also develop at the expense of the juvenile stages of the *Euphyllura olivina* (Costa) and is present in adult form on the blossoms of the plant during the long flowering period.

In recent years, especially in view of the substantial reduction of chemical treatment with insecticides, herbicides and fungicides and the reduction or even elimination of tillage due to the promotion of natural weed growth in various olive-growing regions, the agricultural ecosystem is subjected less to such cultural practices which can all in some way hinder the consolidation of these complex relationships. For these reasons, the agricultural ecosystem has been seen to be in a state of good health, especially in regions close to wooded stretches containing plants that are typical of the Mediterranean basin as these can constitute areas of refuge for the natural antagonists of harmful species.

GENERAL REMARKS ON PLANT PROTECTION

Pest management in olive cultivation has made considerable progress in recent years. From the beginning of the century up to the fifties, the only harmful species controlled chemically was the olive fruit fly. For this insect, which has been known since antiquity (Pliny referred to a *vermiculatio* of the olives which in some years damaged production), the contribution of two leading figures of Italian entomology, Antonio Berlese and Filippo Silvestri, has proved decisive. These two scientists, and in particular the former, shed light on certain fundamental aspects concerning the biology and population dynamics of this dipteron as well as the development of strategies to control it, which are still being applied today, albeit with considerable changes as regards the chemicals used. Silvestri also made very significant contributions to research on the natural antagonists of the *B. oleae* and of the fruit fly *Ceratitis capitata* (Wied.) in tropical and sub-tropical regions. Further valuable research on the olive fly was carried out by Antonio Melis.

With the advent of synthetic organic substances, especially organophosphates and carbamates, chemical pest control, with its immediate results, spread rapidly in all the olive-growing areas of the Italian peninsula and in the most important olive-growing countries. Treatment against even occasionally harmful species has intensified down to the present day, and in certain areas where modern pest control techniques have not been accepted, the burden of chemical treatment (primarily using insecticides) to which the agricultural ecosystem is being subjected, is excessive. Until a few years ago, there were in Italy at least three methods of traditional pest control against the fruit fly, one or two methods against the moth, and virtually always another to fight the black scale (*Saissetia oleae* (Olivier)). These types of treatment, often carried out during a rather limited span of time (May-October) when the concentration of beneficial insects (entomophagous, pronubial) is at its peak, decimate these populations and cause sudden explosions of phytophagous insect populations. A case in point are the populations of the *Saissetia oleae* (Olivier) which have existed up to recent times alongside those of other coccinellid species such as *Lichtensia viburni* (Signoret), the *Parlatoria oleae* (Colvée) and the *Pollinia pollini* (Costa), all of which can cause serious damage to plants.

If the ecosystem is not balanced, these insects remain constantly under the destruction threshold, as a result of the continuous work of the large number of natural antagonists.

It was clear that the types of treatment applied at pre-established intervals were not producing the satisfactory results attained at the outset. This was due to the inevitable substantial numerical increase of the species, previously present at low density, as well as to the development of resistance by the insects with one part of the population no longer being affected by the toxic action of the active principles). There was also a serious impact on the environment and the amount of undesired residues in foods was on the increase.

By the late fifties, a strategy had been developed known as integrated protection. We had to wait until the end of the sixties, however, for public opinion to become aware of these urgent, yet often neglected problems. Initially, efforts were geared to more flexible protection. Treatment was no longer applied at scheduled intervals but whenever the harmful species appeared, using empirical damage thresholds (the loss in crop value resulting from the increased density of the phytophagous insect equalled the cost of the action required to prevent it). Protection was then geared to more complex strategies for the control and management of the agricultural ecosystem, moving thus towards integrated pest management (IPM). Integrated pest management is a strategy used to maintain the harmful organisms below the density level which causes economic damage, taking full advantage of natural regulatory mechanisms and using any methods of pest control that are acceptable from the ecological, economic and toxicological points of view. Considerable results have been obtained over the last twenty years for the protection of olive orchards. Our knowledge of how the agricultural ecosystem functions has increased, sampling methods have been developed, and economic thresholds have been set for the principal phytophagous insects. Entomophagous antagonists previously unknown in the Mediterranean area have been introduced, and strategies for more selective pest control have been developed. These advances have enabled this complex agricultural ecosystem to recover in part while maintaining its complexity.

PLANT PROTECTION IN THE MAIN OLIVE-GROWING COUNTRIES

The olive is a plant that has numerous phytophagous species, a simple listing of which would be a lengthy undertaking. Some of these can pullulate in just a few years (at times abetted by incorrect measures for plant health care) and cause economic damage. In the Mediterranean area, there are essentially three species of insects which can attain such density as to cause fairly frequent damage to production: the olive fruit fly (*Bactrocera olea* (Gmelin)), the olive moth (*Prays oleae* (Bernard)) and black scale (*Saissetia oleae* (Olivier)). The most important of these three species in Italy and, apart from certain exceptions, in the other countries of the Mediterranean basin as well, is the olive fruit fly. Of course, in countries where the olive has been cultivated relatively recently and the fly is not present, the major damage is caused by other phytophagous pests, which have usually been introduced accidentally. This is the case of the *Parlatoria olea* (Colvée) (*Rhynchota Diaspididae*) in the Californian orchards, for example, where it is the key phytophagous pest. This insect, believed to have originated in Central Asia, is also present on the olive and on fruiting Rosaceae in the Mediterranean area but is much less serious from the economic point of view.

Of the three pathogens of the olive, the most dangerous for plants in production is undoubtedly «peacock eye» (*Spilocaea oleagina* (Cast.) Hugh.). This pathogen attacks the olive in all Mediterranean countries and is considered the most widespread mycosis of the olive in the world, even if of negligible importance in regions with a hot and dry climate. It is not easy to estimate the economic damage produced by this disease. In the most serious cases, it can lead to heavy defoliation causing a considerable reduction in yield. The symptoms include injury to the foliage, the stalk and the fruit itself. Usually, 30-40% of the leaves affected can survive. This pathogen is controlled almost exclusively by means of copper products (copper sulphate mixture and oxychlorides).

PRINCIPAL HARMFUL SPECIES

OLIVE FRUIT FLY (*BACTROCERA OLEAE* [Gmel.]) (*DIPTERA TEPHRITIDAE*)

Systematic position

The species, described by Gmelin in 1788 as *Musca oleae*, was known until recently as *Dacus oleae* Gmel. In 1989, Drew divided most of the *Dacini* species into two genera: *Bactrocera* Macquart and *Dacus* Fabricius. In the former, all the abdominal tergites are free whereas in the latter they are fused. Drew therefore classified the fly as belonging to the *Bactrocera* genus (sub-genus *Polistomites* Enderlein). Then, in 1992, White and Elso-Harris, while accepting Drew's distinction between the general *Bactrocera* and *Dacus*, considered that the *Bactrocera oleae* was part of the subgenus *Daculus Speiser*, which comprises only the *oleae* species. The distinction between the *Bactrocera* genus and the *Dacus* genus is further justified by differences in biology and geographic distribution: more specifically, the *Dacus* genus includes species which attack capsules and pods of *Asclepiadaceae* and *Apocynaceae* or fruits and flowers of *Cucurbitaceae* and are to be found in the tropical and temperate regions of the Old World. We shall adopt the new nomenclature and refer to the olive fruit fly as *Bactrocera oleae* instead of the older and better known name of *Dacus oleae*.

Bactrocera oleae is the only fly in the Mediterranean area closely linked to the olive (*Olea europea L.*), whether cultivated or wild. Its juvenile stages develop inside the olive fruits. The species is found throughout the Mediterranean region, the Canary Islands, Pakistan, the Caucasus, Egypt, Eritrea and South Africa. In other regions of the world where olive cultivation has been introduced recently, such as the United States (California, Arizona), South America, China and Australia, the species is not present.

Description of the adult insect and of the pre-imaginal stages

The adult is a fly of medium size, about 5-6 mm long, with a wing span of about 12-14 mm, with brownish red palps and proboscis. The compound eyes are iridescent bluish-green. The thorax is dark with yellow post-pronotal lobe and scutellum; the sides are fulvous. The wings are hyaline with a typical brown spot on the apex, corresponding to the third longitudinal vein. The abdomen is fulvous with black spots in the lateral areas of the first 4 segments, of variable shape and size. The female is easily distinguishable from the male in its abdomen, which is considerably wider in the central part and sharp at the distal end. The last segment is an aculeus which can puncture plant tissues in order to lay eggs under the epidermis of the fruit. In the male, the edge of the third abdominal tergite has a series of about 12 bristles.

Egg

The egg is elongated, whitish in colour, with a tuberculiform micropylar pole. It is about 0.7 mm long and 0.2 mm wide.

The chorion looks smooth unless highly magnified but is in fact lightly sculptured with a polygonal pattern due to the impression of the follicular cells. The aeropyles can be seen on the points of contact of these formations.

Larva

The larva, creamy in colour, has a sub-cylindrical body and, like all Muscomorpha, three larval stages.

The first stage, when the integuments are transparent, shows the openings of the respiratory system only in the last abdominal urite (metapneustic), while in subsequent stages not only posterior but also anterior tracheal spiracles (amphipneustic) can be seen. The larva

Bactrocera oleae (Gmel.). Female depositing eggs in an olive.

of the third stage presents ambulacral areas only on the prothorax and on the abdominal segments. It is about 6-7 mm long and 1.3 mm wide. The head is small and has a typical «facial mask» on each oral lobe, a series of 11-12 lamellae of rather regular pattern. The cephalopharyngeal apparatus is characterised by rather sharp, robust mouth unci which are grooved in the distal part. The intercalary sclerite (H-shaped) is not fused with the vertical sclerites. The anterior tracheal spiracles lead to the distal part of the prothorax in the lateral-dorsal position and usually consist of 9 spiracular lobes. Each of the posterior spiracles has three lip-shaped openings, surrounded by groups of typical spiracular bristles with branching patterns.

Puparium

The puparium, elliptical in shape, is typically a 'barrel' consisting of the old hardened larval cuticula. All the segments of the larva are now recognisable, with odontoid production, spinule, etc., with the exception of the head, which is invaginated inside the puparium. The colour varies from whitish to yellowish, depending on the state of desiccation of the epidermis. It ranges from 4-5 mm long to 1.5-2 mm wide.

Inside the puparium, owing to distribution processes of the epidermic larval cells as well as renewal from imaginal disks of all the typical structures of the adult insect (head, compound eyes, thoracic appendices, abdomen, etc.), the typical pupa exarata will form after a variable period of time. This process is commonly called nymphosis.

Biology and etiology

B. oleae is a species found throughout the Mediterranean basin, from coastal areas and plains to the limits of olive cultivation. The fly is closely linked by nature to the olive (cultivated and wild), even though laboratory experiments have shown that it can develop in the fruits of other *Oleaceae* such as *Ligustrum* and *Jasminum*.

The number of generations depends essentially on two parameters: the temperature and the moment of receptivity of the olive. In cold regions, the fly may not complete its own development cycle whereas in warm regions it is theoretically capable of developing uninterruptedly throughout the year. The fly can then develop one or more generations, depending on those factors which, from year to year, determine the severity of the attacks.

The species can winter as larva in the drupe, as pupa in the ground or even in adult form. The climate pattern in the various olive-growing regions will determine the mortality of the wintering stages. The pupal stage is obviously the most likely to survive.

The period between the time when the adults come out of their cocoon in the spring and the time of receptivity in the drupes upon egg-laying is also of importance. The longer this period, the higher the mortality of the fly populations and thus the less serious the attack of the first generation.

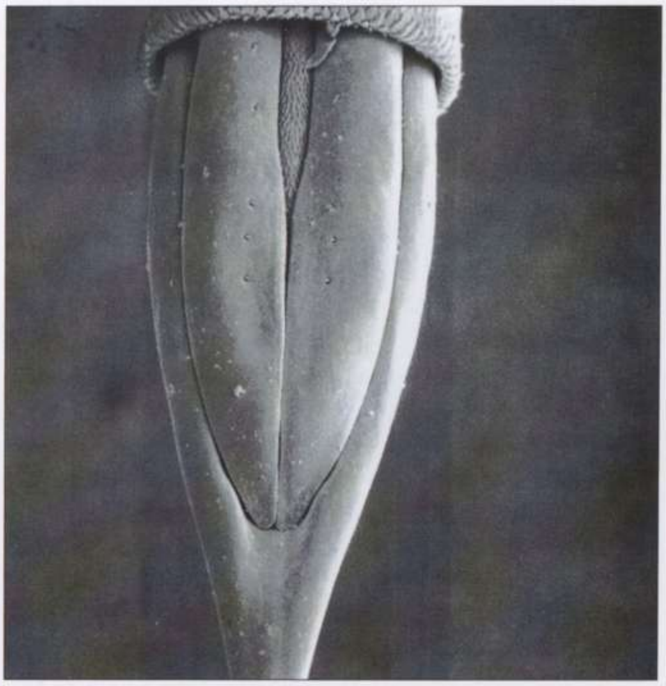
The adult

Once nymphosis has ended, the fly uses the pthyline (a swollen small cushion of blood temporarily present in the head) to break the puparium, along existing pre-rupture lines, and thus emerge. The wings soon unfurl, and the adult insect can now fly and initiate trophic activity. Both males and females are sexually mature about 6-8 days after emerging from the puparium. Mating usually occurs after this period, primarily in the late afternoon. The courting period is characterised by intense agitation by the males which rotate their wings in a characteristic motion, thereby producing friction on some bristles on the third abdominal tergite. This creates a characteristic sound called «stridulation,» a phenomenon prevalent among Diptera and in many other species of insects, typical of the preliminaries to mating. To attract the male, the female of the *Dacus* emits a sexual pheromone which is extremely volatile and characterised by various synergic fractions but is captured by the sensory receptors of the male even at relatively long distances. The fraction of the pheromonic substance which, as far as we know, is the most active in mating, is an isomer of spiroacetatal 1.7 - dioxaspire (5.5) undecane.

The characteristic prick marks of oviposition.

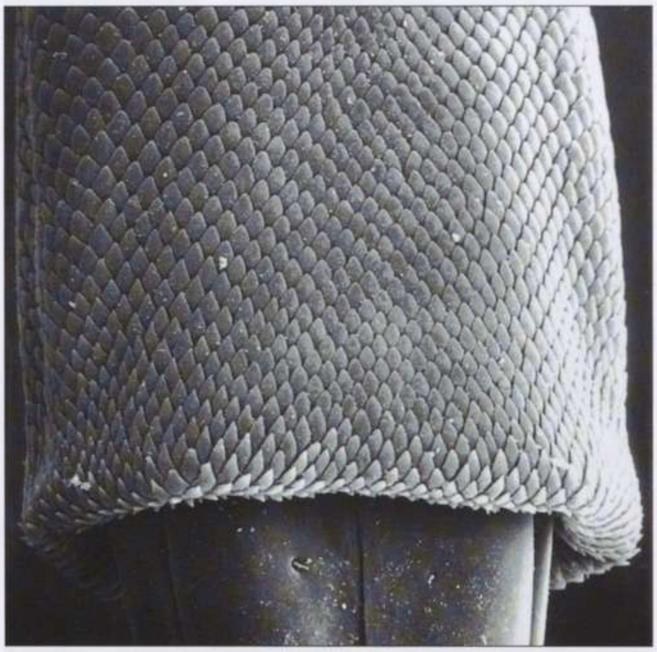
Industrial production of pheromonic substances has opened up a new field of applied entomology. These substances have been used to monitor the populations present in agricultural ecosystems and also for massive trappings of certain phytophagous insects («sexual confusion»). This technique involves the use of special devices to release appropriate quantities of synthetic pheromone in the agricultural ecosystem to confuse the males so that they will not seek to fecundate virgin females.

As regards the olive fly, the synthetic pheromone is used chiefly to monitor the adults. Various experiments conducted by research teams in different olive-growing regions in the Mediterranean have nearly always revealed a total lack of correlation between captures with traps primed with synthetic pheromone and the percentage of infestation in the drupes and this fact considerably limits interest in the practice. If such a correlation did exist, it would no longer be necessary to apply the sampling method on the drupes in order to estimate the infestation of the olive orchard by the olive fruit fly.


Bactrocera oleae (Gmel.). Tip of the ovipositor.

A temperature of at least 17°C is required for mating and laying of eggs. Once mating (which lasts between one and two hours) is over, the fertilised females can lay their eggs in receptive olives. Receptivity is determined by the change of certain chemical and physical parameters of the drupe. The commencement of this phase is thus of great importance for the biology and, consequently, for the control of the fly. The female, with its abdomen arched, punctures the epicarp of the drupe with the lance-shaped ovipositor and normally lays one egg per fruit. During laying, owing to mechanisms which are not yet clear, the female transmits to the egg the symbiotic bacteria present in the diverticulum above the oesophagus and in the other tracts of the digestive system. A certain number of drupes may have what are known as «sterile punctures», as the females may puncture the drupe with the ovipositor without laying any eggs. Exceptionally, in years of a considerable mass of adults and few olives on the plants, more eggs may be laid in the same drupe. A female insect may lay several hundreds of eggs in the course of its life. The puncture can be seen on the drupe as a small, necrotic, sub-triangular area which tends to suberificate after a few days. The egg is laid under the epicarp of the drupe. The period of embryonic development depends to a great extent on the temperature. Constant temperatures of 10° and 31° C appear to be the lower and higher limits for this stage. Embryonic development is completed in 18 days at the lowest temperature, and in only two days at the highest temperature. Zero development (that is, the temperature at which the species should theoretically remain at the same stage of evolution for an unspecified period) is 8.2°C and the thermal constant, Thc, (the product of the duration of development at a known temperature obtained from the difference between this temperature and zero development) is 48.6°/d. The mortality rate is considerable at temperatures above 31°C. It is important to know these development thresholds for the monitoring and control of the fly. Summer temperatures, especially inside the drupe, frequently exceed the 31°C limit, causing considerable mortality amongst the eggs and the young larvae. In such cases, even if the economic intervention threshold is passed, treatment should not be applied, because of natural mortality.

Once embryo development is complete, the larva emerges from the egg and begins to feed on the pulp of the olive, thanks to the valuable work of the symbiotic bacteria transmitted by the female through the egg. The action of these bacteria is indispensable for the feeding of the newly-born larva because they contribute to the enzymatic hydrolysis of the proteins. The trophic courses are at first rectilinear and near the surface; with time, the larva tends to turn increasingly towards the interior of the drupe. The galleries become more sinuous and larger in size due to virtually continuous growth. The age of the larvae can in fact be determined from the diameter of the excavated galleries. Development lasts about 25 days at a constant temperature of 15°C and



Bactrocera oleae (Gmel.). Detail of the eighth urite.

drops to 10 days at a temperature of 22ºC, which usually occurs during the summer period. The thermal constant is about 116.6º/d, with zero development at 10.7ºC.

When the larva reaches maturity, it cuts the epicarp of the drupe with the mouth unci, making a characteristic circular hole, and then drops to the ground, where it is impupated at shallow depth. In the hot and dry summer period, impupation may take place within the drupe itself.

The majority of the population survives the winter period in the pupal stage. The duration of this stage, at constant temperatures, ranges from 90 days at 10º C to 9 days at 35ºC. Zero development is 9.5ºC, and the thermal constant 200.1º/d.

The entire growth period (egg-adult) is characterised by a zero development of 10ºC and a thermal constant of 375º/d.

Number of generations

As already pointed out, the fly may complete a variable number of generations, depending on the temperature which influences both the phenological phases of the plant and the development of the insect itself. This dependence on temperature can be interpreted using different methods of calculation. One of these, known as the «thermal sum» can be expressed with the following formula:

$$t(T-c) = Thc$$

where t is the mean time of development at temperature T, and c is the figure for zero development. The constant, Thc, is expressed in degrees/day.

Zero development is obtained using the formula:

$$c = T = t1(T-T1)t1-t$$

where T and T1 are the experimental temperatures, t and t1 the relative mean times of development. This formula can be used to calculate the theoretical number of generations of a given species. This is done as follows: the thermal sum equation, $t(T-c) = Thc$, yields a mean temperature or constant T; the development time t is $t = Thc/T-c$. The calculation can be carried out once the daily mean temperatures and the period in which the orchard is susceptible to attack are known. Taking the entire development of the insect (egg-adult) as 100, and t being expressed in days and fractions of a day, the daily development speed V (in percentage) will be: $Vs = 100/t$. The duration of one generation is obtained from the sum of the daily percentages up to 100.

On the basis of theoretical constants obtained in the laboratory, and knowing when egg-laying starts (determined in the field by assessing the hardness of the pit), it is possible to calculate the generations of the fly. The situation in Tuscany can serve to illustrate this point. In this region, it is possible, on the basis of thirty-year meteorological and climate data, to identify five different climate zones (12º-13ºC; 13º-14ºC; 14º-15ºC; 15º-16ºC; 16º-17ºC), characterised by different annual temperature means. These zones range between 12-13ºC (olive orchards in the Piedmont region) and 16-17ºC (olive orchards in the southern coastal regions). There are no cultivated olives below the 12-13ºC zone. By means of the known theoretical constants of the fly (c= 8.99ºC and Thc = 379.01º/d) relative to the entire pre-imaginal development at variable temperatures, the commencement of egg-laying as observed in the various climatic zones and the temperature means, it was possible to calculate the theoretical number of possible generations. This has in turn made it possible to subdivide Tuscany into different «fly risk» zones in which one or more or no generations can reach completion. It was then demonstrated how the fly can, in the 12-13ºC and 13-14ºC climate zones, complete one generation at most during the summer-autumn period, and at least three full generations in the 16-17ºC climate zone. Obviously, the greater the number of possible generations, the higher the risk.

Damage

Damage caused by the olive fruit fly can be direct, in the case of table olives, or indirect, in the case of oil

Captured male and female flies.

olives, because of the processing which the drupes undergo. For these reasons, a clear distinction must be made between these cultivars.

Table olives intended for direct consumption must have no lesions or alterations if they are to fulfil the rigorous quality criteria. Table olives are attacked before oil olives because by June or July they are already receptive for egg-laying (according to the region).

Different types of damage can occur in olives intended for processing as oil. First of all, the drupes may drop prematurely with an intensity directly proportional to the presence of progressively more advanced stages of development. In years of scarce production, this phenomenon may cause the entire loss of the crop, while in years of heavy crops the premature drop caused by the fly ranges from 10% to 50-60%, depending on the variety and the region in question. The presence of the larva causes loss of part of the pulp although this is negligible considering that, to reach maturity, the larva removes from 50 to 150 mg and anyway such damage is offset by the considerable increase in weight of the olives which remain on the plant. The real damage therefore is that affecting the quality of the resultant oil. Depending on the percentage of infestation, alterations produced by the presence of mature larvae or galleries with «exit holes» increase, especially in terms of acidity and the number of peroxides, with immediate impairment of the quality of the oil. Acidity increases due to the hydrolysis of the fatty acids, catalyzed by the enzymes produced in the course of maturation and accelerated due to contact with oxygen, especially by the action of the bacteria and fungi which develop in the galleries of the infested drupes. Other alterations occur in the aromatic fractions which are responsible for the organoleptic characteristics of the oil and in the polyphenols which help to stabilise acidity. In a seriously infested batch of drupes, if harvesting and pressing are carried out in time, initial acidity can be kept below 1% but, if such stabilisers are only present in low quantities, acidity can soon reach levels of 5-6%.

The financial losses caused by such damage to quality have led to attempts to draw up economic thresholds for intervention, that is, to establish the population density of phytophagous pests at which action to thwart economic damage should be taken. Such thresholds have to take into account so many parameters – production, cultivar, period, the incidence of abiotic and biotic factors, the impact of chemical treatment on humans and the environment, etc. - that calculations are enormously difficult.

Natural enemies

There are very few parasites of the fly in the Mediterranean basin: four ectophagous Calchidoid Hymenoptera, namely, *Eurytoma martellii* Dom., *Eupelmus urozonus* Dalm., *Pnigalio mediterraneus* Ferr. & Del. and *Cryptoptyx latipes* (Rond.), and one endophagous Braconid hymenopteron, *Opius concolor* Szepl., present in the Mediterranean only in North Africa, Palestine and the islands of Crete, Sicily and Sardinia.

In addition to these, many others from West Africa, Eritrea and Southern Africa are known and attempts have been made, especially by Silvestri, to introduce and acclimatise them to Italy, but without success. Unfortunately, such attempts have so far proved unsuccessful, probably because of our scarce knowledge of the biology of these parasites and because of the small numbers released.

Of the four ectophagous pests present in the Mediterranean area, the most active and widespread are the *E. martellii*, the *E. urozonus* and the *P. mediterraneus*. Much rarer is the *C. latipes*. These species are present in olive orchards from July to October. Once a third stage larva of *B. oleae* has been identified, the female paralyses it by pricking it with the ovipositor. It then lays an egg on the body of the victim. The larva which develops is ectophagous (attacking the victim from the outside) and, once it attains maturity, pupation takes place inside the gallery. These species do not winter at the expense of the fly, with the exception, in a few cases, of the *P. mediterraneus,* which, depending on the climate, can remain active throughout the year, undergoing only a slowdown of activity in winter. The presence of ectophagous insects in olive orchards varies widely in terms of both time and space. Presumably, this discontinuity is due to the presence or lack of the victims required for reproduction in the spring and winter. These victims are represented by other host species present on spontaneous or cultivated plants which are parasitised during specific periods of the year because, as in the case of the ectophagous insects of the fly, they constitute the host on which they can winter. A simple example of this is the well-known case of the *E. urozonus* which usually winters as a pupa inside the galls produced in the flower organs of the *Inula viscosa* Ait. by the larvae of the Tephritide Dipteron *Myopites stylata* Fab.. These ligneous galls, which remain on the dried-up plant, constitute a secure wintering site. In Tuscany, the *E. urozonus* may also winter as a pupa under the dried-up body of the female of *Saissetia oleae*. *E. urozonus* behaves as an optional hyperparasite which in autumn attacks the larvae of the *S. cyanea* Motsch., the oophagous predators of the *S. oleae*.

The *Opius concolor*, on the other hand, lays its egg inside the body of the fly larvae (preferably those in the 3rd stage) and, unlike the ectophagous insects, can winter in the soil, protected by the puparium of the dipteron. It is well known, however, that this parasite can survive winter adversities also in adult form. The Braconid, which is present only on the islands of Sicily and Sardinia, has often been introduced into southern Italy, a few regions of central and northern Italy (Tuscany and Liguria), the South of France and certain regions of Spain, Yugoslavia and Lebanon. However, there have been no reports of stable acclimatization. Such lack of success is generally attributed to the small numbers released and to the presumed low resistance to low temperatures. In our view, however, the real reason is that other important restrictive ecological factors are probably at work in these regions. From spring until the beginning of the summer, in the absence of *Bactrocera* larvae, the Braconid must find other victims in the agricultural ecosystem. These are known in a few regions in North Africa and in Sicily and are represented by other Tephritide Diptera such as *Ceratitis capitata* Wied., which live on the fruit, enabling the Braconid to reach the third-stage larvae with the ovipositor; *Carpomyia incompleta* Beck. on *Ziziphus* spp. and *Capparyimia savastani* Mart. on *Capparis spinosa* L.

Opius concolor Sezpl. Active female on an olive branch.

In southern Italy, in the sixties, the *O. concolor* was released in biological control programmes using the flooding method. This was possible thanks to the development of mass rearing programmes using the *Ceratitis capita*, which can be easily reared on artificial substrates, as substitution host.

OLIVE MOTH (*PRAYS OLEAE* [Bern]) (*LEPIDOPTERA HYPONOMEUTIDAE*)

Systematic position and distribution

In the Palaearctic region, the genus *Prays* comprises 2 harmful species: *Prays oleae* and *P. citri*. *P. oleae* is found in all areas round the Mediterranean and the Black Sea, where the *Olea europea*, its favourite host, is prevalent.

Description of the adult and of the pre-imaginal stages

The adult is a small, silvery-grey coloured moth with small spots on its anterior wings, variable in number and position. The posterior wings are fimbriated lengthwise. The body is 6.5 mm long and the wing span about 13 mm.

The egg is lenticular, elliptical, white when laid, and measures 0.5 mm. The chorion has an irregular polygonal sculpture.

This species has 5 larval stages. The mature larva measures 7-8 mm, and has a pale brown-greenish colour; it also has two characteristic olive-coloured submedian dorsal stripes and two yellowish lateral stripes.

When it reaches maturity, before it turns to a chrysalis, the larva develops a thin, whitish, sericeous cocoon. The chrysalis measures about 6 mm and is brownish in colour. Numerous long and strong uncinate bristles are present on the last urite. The cremaster consists of 6 uncinate bristles for maintaining the nymphal exuvia in place when the moth comes out of its cocoon.

Biology

Like most of the species of the genus *Prays*, *P. oleae* is also characterised by having several generations in a year, which develop by living at the expense of the different parts of the plant. The first generation feeds on the flowering organs (anthophagous generation), the second generation on the fruits (carpophagous generation) and the third on the leaves (phyllophagous generation), with larvae which start by mining and, in the final stage, erode the lower leaf blade from the outside. When the species has no flowers or fruits at its disposal, all three generations can live at the expense of the leaves.

The first adults of the year coincide with the differentiation of the flower buds of the olive. They are active at dusk at temperatures higher than 13°C. The virgin females emit a sexual pheromone, the main constituent of which is (Z) - 7 tetradecenal; after mating, they lay isolated eggs on flower buds. Each female can lay up to 300 eggs. However, according to the Spanish literature, each female lays between 30 and 100 eggs. The larvettes are born after about a week, and penetrate inside the buds, gnawing at the internal organs, and passing from one bud to the other, gagging the infested buds with thin sericeous threads. Each larva can destroy 15 to 40 buds, and at the end of development turns into a chrysalis between the floral racemes. At the end of nymphosis which lasts 6-9 days, the new adults emerge and lay their eggs on the calyces of the drupes (size of a grain of pepper). At temperatures exceeding 31°C, the mortality rate of the eggs and young larvae is high, especially at relative humidity levels below 70-75%. The newly-born larvae penetrate the olive directly from the ventral face of the chorion, and immediately enter the endocarp (stone) before it starts to harden. Once in the endocarp they remain for about a month in its periphery, and when the seed moves from the aqueous to the gelatinous phase, they attack it rapidly. At maturity, they abandon the olive, producing a characteristic circular hole near the stem, and in general turn to chrysalis between two leaves which are touching or on the soil, if in a drupe which has fallen to the ground. The adults emerge in September - October. The females of this generation usually lay their eggs on the lower blade of the leaves; the larvae penetrate the leaf by excavating a filiform gallery in a serpentine pattern. When the first mutation has been completed (February - March), the larva abandons the leaf and moves to the lower blade of another, which it penetrates, producing a circular or C-shaped mine. When the second mutation has been completed, the larva moves to a subsequent leaf, excavating a roundish or patchy gallery. The fourth stage larva excavates wide, sub-rectangular or oval galleries, while the fifth stage larva, on account of its size, usually erodes the lower blade from the outside. As this usually occurs when the olives begin to vegetate, the fifth stage larvae sometimes also reach the buds where they erode the leaflets. They usually turn to chrysalis on the lower blade and, after about two weeks, the adults of the antophagous generation emerge in May.

Damage

The damage caused by the antophagous generation is not easy to quantify because of the concurrent natural fall of the flowers. In general, however, in oil olive varieties, thinning of the flowers does not reduce yield unless infestation is exceptionally serious. Damage caused by the phyllophagous generation is also irrelevant.

Only the carpophagous generation, at least as regards Italy, can cause real damage and economic loss. The young larvae which attack the olives in the pepper grain stage cause a small amount of fruits to fall. A second fall, which is usually more serious, occurs in September - October, due to the emergence of the mature larvae through the peduncle.

Natural enemies

The number of natural antagonists of the *Prays* is truly remarkable and comprises some forty species belonging to various Orders. Among the diptera, two important species are worth mentioning: the *Phytomiptera nitidiventris* Rond. (Diptera Tachinidae), and the *Xanthandrus comtus* Harr. (Diptera Syrphidae). The former is a parasite and the latter a predator of Lepidoptera of interest for agricultural reasons. The Hymenoptera include numerous species belonging to the families of the Ichneumonidae, Braconidae, Chalcididae, Elasmidae, Encyrtidae, Eulophidae, Eupelmidae, Platygastridae, Pteromalidae and Thrichogrammatidae. The most active species, which have been subjected to mass rearing, are *Chelonus eleaphilus* Silv. (Hymenoptera Braconidae) and *Ageniaspis fuscicollis* Dalm. (Hymenoptera Encyrtidae). The Braconidae are an ovo-larval parasite present in various areas of the Mediterranean. Like its host, it has three generations and its action varies. It can be reared on a substitution host and then introduced into new areas. *Ageniaspis fuscicollis* is likewise an ovo-larval, endophagous, poly-embryonic parasite, which seems to play an important role, attaining rates of parasitization of up to 75%. Finally, the Trichogrammatidae are of importance because, by living on the egg, they contain the infestation at the nascent stage; they, too, can be reared on substitution hosts.

Among the predators, in addition to the Syrphid fly *Xanthandrus comtus*, of interest are the *Chrysoperla carnea* (Neuroptera Chrysopidae), an active predator of eggs and young larvae, and *Anthocoris nemoralis* F. (Rhynchota Antochoridae).

BLACK SCALE (*SAISSETIA OLEAE* [Oliv.]) (*HOMOPTERA COCCIDAE*)

Systematic position and geographic distribution

The *Saissetia oleae* belongs to the family of the Coccidae. This family comprises some females which lay their eggs inside a ceraceous sac which they produce themselves and others (as with the *Saissetia)* which lay their eggs under their own bodies. The desiccated exoskeleton of the female which dies at the end of egg-laying continues to provide protection for the eggs. The species, although reported at the end of the 18th century in the Mediterranean area, appears to originate from South Africa. It is currently present throughout the world, particularly in temperate climates. This coccinellid species is notoriously polyphagous, and can live on spontaneous and cultivated species; among the latter, it is extremely common and harmful to olives and citrus fruits.

Biology

S. oleae in the Mediterranean area is characterised by slow development, with 1-2 generations at most. The male seems to be very rare. The females, which reproduce by parthenogenesis, have a heterometabolic type of development with the following ontogenesis: firstly the egg, then first, second and third stage neanid, then the female. For practical reasons, the last stage is divided into pre-oviferous and oviferous, when egg-laying commences.

The female has an oval body and is characterised by a conspicuous double-crossed carina on the back. The colour varies with time. Soon after mutation, it is grey and the body is flattish and oval. With the commencement of the maturation of the ovaries, however, the body becomes rounded and darker, attaining a lead-grey colour.

When egg-laying starts, the female is at its final size and colour which is virtually blackish. Size varies considerably, from 1.8 to 5.5 mm in length, and from 1 to 4 mm in width. Fecundity depends also on size, and the number can range from 150 to 2,500 eggs. A female of average size lays 500 to 900 eggs.

When laid, the egg is whitish in colour, but pinkish towards eclosion. The egg-laying period lasts from 10 to 15 days in May - July, but may be considerably longer for that part of the population which can lay its eggs in September - October. Embryonic development depends to a large extent on temperature. At 25°C, it can be completed in 12 days, while at 18°C it takes about 38 days. In central Italy, the period with the maximum number of egg-laying females is in July.

Egg-laying female lifted from the branch to reveal the eggs beneath her body.

The newly-emerged neanids have the task of colonising the young leaves. This stage is the most vulnerable to attack by abiotic agents, as it is also the least protected from ceriferous secretions. In central Italy, the period with the maximum number of first-stage neanids is August -September. The three neanid stages can be differentiated macroscopically by colour, as well as by shape and size. The first-stage neanid is yellowish, as is that of the second stage, and does not exceed 0.7 mm in length; the second is between 0.8 and 1 mm long, and the third is initially yellowish, then grey, with a highly conspicuous carina, and measures 1.1 to 1.6 mm in length.

Third-stage neanid on the back of an olive leaf.

Saissetia oleae Oliv. Severely infested olive branch.

In the Mediterranean area, wintering is entrusted to the second and third stage neanids; young and egg-laying females may also winter, but in smaller percentages. The generation is then completed in spring - summer. Then in September -October, a small part of the population which has emerged prematurely can complete its development and become adult, egg-laying females, thus completing the second generation.

Damage

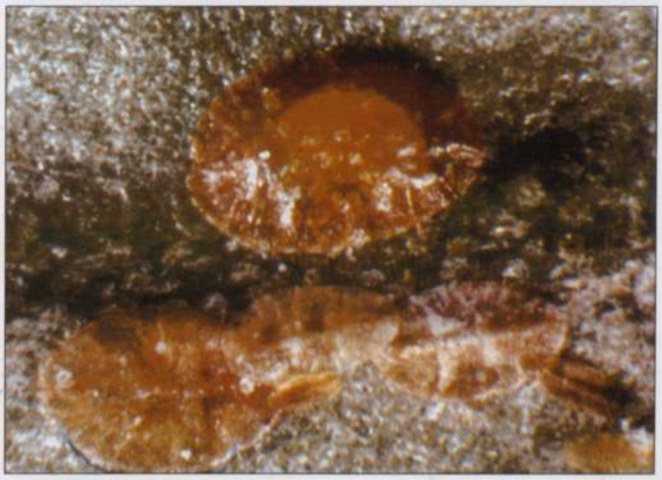
The damage caused by this pest is essentially due to the extraction of sap and to the emission of honeydew (excrements rich in sugar). Fungi grow on these (*Capnodium spp., Cladosporium spp., Alternaria spp.*, etc.) causing blackish crusts to develop, commonly known as fumagines. These limit the photosynthetic and respiratory capacity of the plant, which often leads to widespread phylloptosis and serious deterioration.

Natural enemies

The control exercised by entomophagous species on this insect appears to be crucial. As the damage caused by *Saissetia* is indirect, its population can be tolerated up to discrete levels of presence, without any real economic damage. In South Africa, where this Coccid is thought to originate, a complex of over 50 entomophagous species lives on it. In the Mediterranean area, however, there are few natural antagonists, notwithstanding the major efforts undertaken to introduce them, in particular parasites of the genus *Metaphycus* (Hymenoptera Encyrtidae).

The most prevalent and important predators in the Mediterranean area include the following species: *Exochomus quadripustulatus* L. and *Chilocorus bipustulatus* L. (Coleoptera Coccinellidae); *Scutellista cyanea* Motsch. and *Moranila californica* How. (Hymenoptera Pteromalindae). Of the Pteromalidae, the former is by far the most widespread and active; the latter, although present throughout the area, is of importance only in certain places. *Chrysoperla carnea* Steph. (Neuroptera Chrysopidae), *Coccidiphaga scitula* Ram. (Lepidoptera Noctuidae) are also present.

Referring only to the main parasites present in the Mediterranean area, we may affirm that from the end of the sixties, two important Enchyrtides, namely *Metaphycus helvolus* (Comp.) and *Metaphycus bartlettii (*Ann. & Mynh.), have been introduced in various countries on several occasions, and are now actively present in the entire area. This has proved a considerable success, as the active presence of the two species has enriched the very small complex of antagonists which comprised chiefly *Metaphycus lounsbouryi* (How.), very important locally but not uniformly distributed, and *Metaphycus flavus* (How.), which has always been present, but at a low population density. *M. bartlettii*, at present the species which is spreading the fastest, lives on third-stage neanids and females at all phases of development. It is endophagous and generally gregarious (although solitary, if living on third-stage neanids). *M. helvolus* is an endophagous, usually solitary parasite, living on second and third-stage neanids. The actions of these two entomophagous antagonists is of great importance because, although oligophagous



Saissetia oleae Oliv. Second and third stage neanids; at the top is a larva parasitised by *Metaphycus barletti.* The endophagous larva of the hymenopteran can be seen through the transparent walls of its host.

species (they live chiefly on coccinellids of the *Saissetia* and *Coccus* genera), they can also survive only on second and third-stage neanids of *Saissetia oleae* which are present all year round. Their action only slows down during the colder months. Their ample and rapid diffusion is undoubtedly due to the constant presence of the receptive stages. Other important entomophagous antagonists, such as the *Scutellista cyanea*, whose larvae prey on the eggs of *S. oleae*, are very active and well represented, but they carry out their action in a brief period of the year during which the egg-laying females are present and they need to trace victims for the other periods but these are not usually present in the olive orchard. In this agricultural ecosystem, in fact, egg-laying females of *Saissetia* or other coccinellids such as *Lichtensia viburni* Sig. are encountered only on rare occasions.

INTEGRATED PEST CONTROL IN OLIVE CULTIVATION

OBJECTIVES

Integrated pest control basically involves monitoring development of the most important phytophagous pests: *Bactrocera oleae*, *Prays oleae* and *Saissetia oleae*. In most olive-growing areas, eco-resistance factors (abiotic and biotic factors of containment) are usually sufficient to keep the moth and black scale populations below the economic damage threshold, although this is not the case with the fly. The main objective of olive protection in all Mediterranean countries, therefore, is to control this species, which is the key insect of the agricultural ecosystem. This is usually done in two different but compatible ways: by stepping up natural pest control by antagonists and by applying the most selective chemical methods possible. The first method entails introducing antagonists, such as the *Opius concolor*, where appropriate, taking into consideration the fact that in certain olive-growing countries, the fly does not exceed the economic intervention threshold every year. There are, in fact, very few parasites present in the Mediterranean area and none of those existing, such as the ectophagous Hymenoptera *Eurytoma martellii*, *Pnigalio mediterraneus* and *Eupelmus urozonus*, have much effect mainly because they need other hosts at certain periods of the year. In order to enhance and prolong their action, the ecosystem should be made more complex with the establishment of plants to host parasites, either within the olive orchards or in the immediate vicinity. Unfortunately, although competent entomologists have been working along these lines, such studies are very complex and very little is known with certainty.

The second alternative is the use of chemical methods although there is an ongoing concern to reduce the number of treatments and to promote techniques with a minimal ecological impact. Efforts are currently geared to promoting the use of poisoned proteic bait which, according to many authors, reduces environmental impact risks. Recent EEC standards (Reg. 3868 and subsequent modifications) for the qualitative improvement of olive oil likewise recommend the use of this method.

Other possible alternatives, still in an experimental phase, include mass trapping techniques (based on the use of chemical attractants to capture large numbers of adults and thus prevent eggs from being laid in the fruit), and the sterile male technique (based on rearing and releasing in the field a large number of sterile males to reduce the probability of fertile mating), already adopted for other Tephritide Diptera such as *Ceratitis capitata*. The latter technique could achieve a drastic reduction in fly populations in the Mediterranean area but requires a joint effort on the part of all the countries concerned. Finally, studies are also developing the sexual confusion method which is already being applied in other agricultural ecosystems.

SAMPLING AND SURVEILLANCE

An essential part of integrated pest control is sampling of the main phytophagous pests with a view to monitoring the flying patterns of the adults and, by taking samples directly on the vegetative organs, to establish the type and degree of the infestation present.

Olive fruit fly

Various monitoring methods are used for this insect, based on the attraction exercised by certain colours (chromotropic cards, usually lemon-yellow in colour) and on chemical attractants of an alimentary or pheromonic nature. Mixed systems are also used in some cases. Although they do reveal flight patterns, these methods are not reliable for estimating the percentage of infestation because there is no strict correlation between the number of individuals captured and the percentage of olives infested. The most widespread method in use in Italy are commercial traps primed with synthetic pheromone and simple yellow chromotropic cards. The advantage of pheromonic traps is that they capture only the males of the fly and are therefore relatively easy to read; their main disadvantage is their cost. Simple yellow cards are not selective and, in addition to capturing both male and female flies, they also capture other insects, primarily Diptera and Hymenoptera. They are not as easy to read, but offer such undeniable advantages as being able to capture both sexes and to provide useful information as to the number of females with eggs. The main disadvantage is that, as they are not selective, they capture a considerable number of natural antagonists present in the ecosystem but this disadvantage is limited by the fact that only three cards are used per hectare and, furthermore, studies may benefit from the sampling of the entomofauna present.

For direct sampling operations, which are the only way of providing precise indications as to actual infestation, a particular method has been developed in Italy known as «reduced» sampling. This is based on the observation of a small number of drupes (about 100-200/hectare), gathered at random, one per plant, every 7-10 days. This method, unlike others developed in the past, provides a rapid, simple and sufficiently reliable view of the infestation in the olive orchard. The drupes are then observed by stereoscopic microscope to distinguish between infested and healthy ones (the latter obviously include drupes with sterile punctures). Infested drupes must then be divided into: drupes with egg, with first-stage larva, with second stage larva, with third stage larva, with pupa, and with exit hole. In order to follow the indications of intervention thresholds, a further distinction should then be made between so-called «active» infestation, comprising eggs and first and second-stage larvae, and total infestation, comprising all stages of development. Damage is inflicted by the various succeeding generations, increasing progressively each time. It is therefore active infestation that has to be used to assess the need for intervention. If we consider third-stage larvae and drupes with an exit hole, any damage which has already occurred would have to be added. To evaluate the final incidence of the damage caused by the fly, a third type of infestation is taken into consideration, consisting only of third-stage larvae and of drupes with an exit hole. As we have already shown, the real damage to production is actually caused by the mature larva which produces the exit hole in the drupe.

The thresholds set in Italy for larvicide treatments are active infestation of 10-15% for oil olives and 2-5% for table olives. For treatments on adult insects, the intervention threshold is set at captures of 3-5 females /trap/week and active infestation of 5%.

The density of fly populations is obviously influenced by both climatic patterns and the alternating production of the olive. More specifically, in a year of heavy crops, the pre-imaginal fly population may be fairly 'diluted' and remain at low levels, even with successive generations, often below the intervention threshold. Continuous monitoring by means of the above-mentioned sampling operations is fundamental in order to avoid superfluous chemical treatment.


Yellow card used to monitor adult olive fruit flies.

A vital element for the development and diffusion of *B. oleae*, meriting separate treatment, is temperature. As we have shown in the chapter concerning the juvenile stages, their development is highly influenced by the temperature. The number of possible generations which the Tephritide can develop and the vital functions of the adults depend essentially on this factor. More specifically, mating and egg-laying are possible only at temperatures of at least 17°C. Conversely, the fecundity of the females is somewhat reduced at 32°C, and no egg-laying takes place at 35°C. The constant monitoring of the temperature and of weather forecasts are, therefore, basic for the control of this pest.

Olive moth

Traps primed with synthetic pheromone are commercially available, making it possible to monitor the flight of the males of the various generations. These data can prove very valuable because they can be used to take direct samples at very specific periods. However, as already stated, it should be borne in mird, that there is no statistic correlation between capture and actual infestation, in particular as regards the *Prays*, where often there is no commensurately high infestation corresponding to high levels of captured population.

As regards sampling of the pre-imaginal population, infestation (percentage of attacked organs) can be determined in the three generations by means of a sample of 100 organs, taken at random from 5-10 plants among every 100 in the olive orchard under examination. The intervention threshold varies, depending on the region, the cultivar, and above all, the various generations. In general, in Italy, the carpophagous generation seems to be responsible for the greatest economic damage to the crop, whereas during the exuberant flowering, infestation of up to 30-40% can be tolerated. Certain authors therefore recommend that pest control against the carpophagous generation should be undertaken when neanids are found in the pit of 7% of the olives of a sample obtained by gathering at least 10 drupes per plant from 10% of the plants present.

Black scale

As regards the *Saissetia*, which causes indirect damage and can thus be tolerated at relatively high population densities, pest control basically comprises containment by entomophagous antagonists which, thanks to recent introductions, are generally able to exert control. The objective remains to acclimatise a greater number of beneficial species. In any event, the presence of black scale at high density in olive orchards is noted firstly in the abundance of fumagines so the degree of infestation can be quantified through appropriate sampling. According to certain authors, the intervention threshold is attained with the presence of 5-10 neanids per leaf, estimated by sampling 100 leaves taken at random from 5-10 plants out of every 100. A very useful sampling operation for determining the time of intervention (with maximum presence of first-stage neanids) can be carried out on the infested parts of the plant, removing 100 females to determine the percentage of those with hatched eggs. When the number of such females with hatched eggs exceeds the 90% mark, chemical treatment can be applied, as we would then be in the presence of a maximum juvenile population.

PEST CONTROL

Olive fruit fly

At the present time, pest control against the fly inevitably involves chemical treatment to be carried out only when the indicated thresholds are exceeded. This proviso has made it possible to reduce the frequency of such applications. Nowadays, chemical pest control uses two different methods, namely the larvicide method, based essentially on the use of phosphorganic insecticides with cytotropic action directed against the eggs and young larvae, and the adulticide method directed against the adults to prevent egg-laying and based on the use of poisoned proteic bait.

Larvicide method

Known also as the «curative» method, this type of pest control gained currency with the advent of phosphorganic insecticides with cytotropic action. This method strikes at the first stages of development of the fly because the insecticides penetrate the drupe. This method has advantages and disadvantages when compared with the adulticide methods. If the intervention thresholds are observed, frequency of treatment is usually limited and infestation is checked in time. The main disadvantage is that, for the treatment to be effective, it has to be applied to the entire foliage. As a result, it strikes indiscriminately at all the beneficial entomofauna and, in particular, at the numerous complex which controls secondary phytophagous pests. Furthermore, the quantities of the active principle and of water per hectare are much greater than those used in adulticide treatment.

Adulticide method

This technique was in essence already used at the beginning of the century in Italy, with bait consisting of molasses poisoned with sodium arsenic, and is based on the attraction exerted by certain alimentary substances on the adults of the fly which ingest the poisoned bait and die before they can lay eggs. This method is currently enjoying renewed interest, especially because the single treatment is less costly, less residue remains in the oil and there is less damage to the beneficial entomofauna. The attractant used today consists of hydrolysed proteins which are poisoned with synthetic insecticides. In view of the fact that insecticide treatment from the air is (rightly) prohibited in Italy, poisoned bait is usually sprayed on parts of the foliage or on alternate plants. Treatment of the entire olive orchard is thus avoided and the ecological impact reduced. Furthermore, the quantity of insecticide distributed per hectare is about one third of that used for larvicide treatment and affects only those insects attracted by the bait. There is some concern that this method is not selective and that, in addition to the fly, entomophagous antagonists such as the *Chrysoperla carnea* are also attracted to the bait. All the same, it is preferred to methods which have a greater impact. The main disadvantage lies in the fact that, if such treatment is applied without taking into account the thresholds and after the receptivity phase of the drupes (hardening of the pit), several applications have to be made. Also, in environments with abundant rainfall in summer and autumn, the treatment has to be repeated because the rain washes the bait off. As already mentioned, however, many authors are now recommending the use of this method at an intervention threshold consisting of the capture of 3-5 egg-carrying females per trap per week and active infestation of 5%, precisely in order to reduce the number of treatments. In addition, a hot and dry summer often produces a high mortality rate among the fly population, especially for the first generation, and the first treatment can therefore be eliminated.

Moth and black scale

As stated above, the only generation of the *Prays* which is subjected to chemical pest control is usually the carpophagous. When the threshold is exceeded, cytotropic phosphoric esters are applied, because the newly-born larva penetrates the olive directly by perforating the ventral face of the chorion which is in contact with it. The only possible treatment for the anthophagous generation, if required, is still that which uses the *Bacillus thuringiensis* Berliner (var. Kurstaki).

The best method of pest control for the *Saissetia* is to increment and enhance the action of the entomophagous antagonists. If absolutely necessary, when the threshold is exceeded, chemical treatment can be applied against first and second stage neanids, using light mineral oils which are efficient and relatively selective with regard to the beneficial entomofauna. If a large number of the young population of black scale appear in September, a phosphoric ester can then be used which also acts against the fly.

PROSPECTS

In conclusion, the olive orchard is a complex and hence a relatively stable ecosystem in most of the Mediterranean, and can today be considered an asset worth preserving. The olive is a plant with a long productive cycle which has always been cultivated in the Mediterranean and the integrated pest control strategy which has gained currency over recent years has helped to maintain the complexity of its ecosystem. It is reasonable to assert that only the olive fruit fly is of fundamental economic importance. An increasingly demanding market as regards oil quality which now takes into account health, hygiene and ecological aspects, requires that growers constantly endeavour to reduce chemical treatment and to optimise agronomic and processing practices. Even so, the most careful plant protection methods can be undermined by incorrect harvesting and pressing. In our view, in addition to the possible methods of control mentioned above (sexual confusion method, sterile male technique), chemical treatment against the fly can now be integrated into more ecological pest control systems. The success obtained with biological control of other phytophagous pests of the olive is a case in point. The introduction of entomophagous antagonists of *Saissetia oleae*, initiated in Mediterranean countries in the seventies, such as *Methaphycus bartlettii* and *M. helvolus*, which spread spontaneously to increasingly larger areas, has already resulted in efficient containment of the black scale population. We must now introduce other such antagonists, as well as preserve and promote the propagation of the entomophagous antagonists already present. There is no doubt that the control of black scale depends on increasing the natural antagonists. The presence of other olive coccinellids at low density may actually help to stabilise the ecosystem, by ensuring the presence of polyphagous entomophagous antagonists such as the Coccinellidae and Pteromalidae. The complex of entomophagous antagonists living on *Prays*, if properly preserved and promoted, is usually sufficient to check this phytophagous pest. In our view, in Italy at least, the populations of Lepidoptera become economically harmful when inappropriate phyto-iatric actions cause the collapse of the pre-existing natural equilibrium, thus fostering the development of other phytophagous pests.

As regards control of the fly, natural antagonists do not play a large part. Yet we must stress that, even if the fly is the most prevalent of the insects, the indirect damage it causes can be tolerated to a greater degree in oil olives than in table olives and, moreover, infestation does not reach the economic damage threshold every year. What is important is that the damage thresholds are defined rigorously and scientifically. They should take into account indirect aspects of costs such as the ecological impact of chemical treatment which is obviously difficult to evaluate and the different situations of olive cultivation in the Mediterranean. It is highly likely that the thresholds established will be conservative in many cases and it is therefore worth considering the promotion of the existing natural enemies and the introduction of new ones. The action of natural containment in the case of this phytophagous pest cannot solve all the problems but it may help increase the frequency of years during which the fly is maintained at harmless population levels. For this to happen, however, we must know precisely how the ecosystem functions. Though such aspects are certainly very difficult to study, integrated pest control is today approaching such problems from a new angle.

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Chapter 7

OIL PRODUCTION AND STORAGE TECHNOLOGY

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OIL PRODUCTION AND STORAGE TECHNOLOGY

Enzo Fedeli

BASIC CONCEPTS

Olive oil is the most ancient edible oil and is still one of the most important constituents of the Mediterranean diet. Today it is also produced and consumed in many non-Mediterranean regions.

In terms of production, Europe comes in first place with 79.6%, followed by Africa (11%), Asia (8.6%) and South America (0.8%). The distribution of consumption can be seen in Table 1.

TABLE 1
GEOGRAPHICAL DISTRIBUTION OF CONSUMPTION (THOUSAND TONNES)

	85/86	86/87	87/88	88/89	89/90	90/91	91/92
Mediterranean Basin*	311.0	317.0	263.0	273.0	236.0	258.0	281.0
EU	1,289.0	1,324.0	1,374.0	1,299.5	1,299.5	1,210.5	1,268.0
North America	46.0	56.5	70.0	71.6	80.0	94.5	101.5
South America	20.5	15.5	17.0	21.0	20.8	19.0	19.0
Australasia	6.6	7.0	7.0	9.0	11.5	13.5	12.5
Ex-USSR	21.8	24.0	23.0	19.0	9.5	5.0	9.0
Others	32.1	40.5	29.0	45.0	62.0	81.5	78.0

*Non-EU members

Table drawn up by SSOG.

PHYSICAL AND CHEMICAL CHARACTERISTICS OF OLIVE OIL AND ITS CONSTITUENTS

The principal fatty acids which form the triglycerides of olive oil are the oleic, palmitic, linoleic, stearic and palmitoleic fatty acids, while there are smaller quantities of linolenic, arachic, behenic, lignoceric and eicosenoic fatty acids.

There are also small quantities of heptadecanoic and heptadecenoic fatty acids (C.17:0; C.17:1). The characteristics of the fatty acids are reviewed in Table 2.

The combustion heat is 9600 cal/g for stearic acid and 9800 for behenic acid; for unsaturated acids it is slightly lower than that of the corresponding saturated acids, e.g. 9450 for oleic and 9350 for linoleic acid (Mattil et al., 1964).

The latent crystallisation heat of certain fatty acids present in olive oil is known to vary from 50.6 cal/g for C16:0 to 57.3 for C24:0; for others it lies between these two limits (Mattil et al., 1964).

The specific heat of certain fatty acids is given here by way of illustration: at 150°C, 0.585 for 18:0 to 0.638 for C18:1 and vaporisation heat of C16:0 (59), C16:0 (56), C18:1 (57) at atmospheric pressure.

The refraction index increases with the rise in the number of carbon atoms in the chain, and the difference between constituents of the corresponding series diminishes as they increase (Mattil et al., 1964); furthermore, it is correlated to the number of double bonds present.

The spectral property in ultraviolet of fatty acids is linked to the presence of unsaturates (200-400 nm) but is of low intensity, if there are no conjugated double bonds as in olive oil. Intensity may increase as a result of oxidising phenomena. The spectrophotometric characteristics of certain fatty acids in olive oil have also been studied (Mattil et al., 1964).

A few indications can be given as to the physical properties of olive oil, bearing in mind that these generally refer to oils that are not defined in terms of origin, acid composition and degree of refining.

For example, the density of olive oil is about 0.9158 (20°C/4°C) and the kinematic viscosity (in centistokes) 46.68 (38°C) and 9.1 (100°C).

Calorific value is 9456 cal/g.

The smoke point is also a measurement that is related to the free acid content and the volatile matter in an oil, especially in the case of olive oil which may be virgin oil or refined oil with varying quantities of added virgin oil (Mattil et al., 1964). For a rectified oil, with no added virgin oil, it is 235°C. The refraction index at 25°C (ns) varies from 1.4665 to 1.4688 depending on quality, with no major differences. The specific extinction in ultraviolet is also variable, depending on the type of oil. This aspect will be discussed in the analytical section.

The specific chemical characteristics of each type of oil will also be described in the analytical section. Table 2 contains indications on the acid value (AI), the saponification value (SV) and the iodine value of the fatty acids in olive oil.

The iodine value in olive oil varies according to the acid composition; up to a maximum of 88 the saponification index is between 185 and 200.

TABLE 2
FATTY ACID COMPOSITION OF OLIVE OIL

Acid	CN	Isomers	MW	AV	SV	IV
Palmitic	16:0		256.4	218.8	208.5	0.00
Palmitoleic	16:1	cis	254.4	220.5	210.1	99.78
Stearic	18:0		284.5	197.2	188.8	0.00
Oleic	18:1	cis	282.4	198.6	190.1	89.87
Linoleic	18:2	cis-cis	280.4	200.0	191.4	181.04
Linolenic	18:3	cis-cis-cis	278.4	201.5	192.7	273.52
Arachic	20:0		312.5	179.5	172.5	0.00
Eicosenoic	20:1	cis	310.4	180.7	173.6	81.75
Behenic	22:0		340.6	164.7	158.8	0.00
Lignoceric	24:0		368.6	152.2	147.1	0.00

CN = Carbon number; MW = Molecular weight;

AI = Acid value; SV = Saponification value; IV = Iodine value.

The maximum non-saponifiable content is 1.5 for oils obtained by physical methods and a maximum of 3 for oils obtained by extraction with solvent.

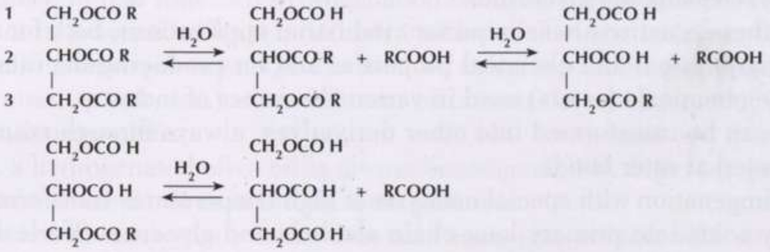
CHEMICAL REACTIONS OF OIL, ACIDS AND THE OTHER CONSTITUENTS

Olive oil is a peculiar combination of many constituents, mostly defined by their chemical identity; their concentration varies according to the olive variety and methods of obtention as well as any refining processes applied.
The most important reactions are obviously those pertaining to the glyceridic constituents and therefore to the fatty acid content. Certain groups of reactions can be established: those affecting the oil considered as a mixture of triglycerides; those affecting the fatty acids, especially the alkylic chain, and those affecting the minor constituents.

These are obviously not restricted to olive oil but can be applied to any vegetable oil or the by-products of any vegetable oil, both for refining purposes and for the production of industrial derivatives. The cost of olive oil means that it is not economic to manufacture other products from the oil itself, only from its by-products.

Hydrolysis and esterification

Hydrolysis and esterification are expressions of the reversible reaction which can convey constituents, in addition to glycerine, from the glycerides to the fatty acids or from the fatty acids to the glycerides.
The reaction can be divided into three stages.



$$\begin{array}{ll} 1 & CH_2OCO\,R \\ & | \\ 2 & CHOCO\,R \\ & | \\ 3 & CH_2OCO\,R \end{array} \underset{}{\overset{H_2O}{\rightleftarrows}} \begin{array}{l} CH_2OCO\,H \\ | \\ CHOCO\,R \\ | \\ CH_2OCO\,R \end{array} + RCOOH \overset{H_2O}{\rightleftarrows} \begin{array}{l} CH_2OCO\,H \\ | \\ CHOCO\,H \\ | \\ CH_2OCO\,R \end{array} + RCOOH$$

$$\begin{array}{l} CH_2OCO\,H \\ | \\ CHOCO\,H \\ | \\ CH_2OCO\,R \end{array} \overset{H_2O}{\rightleftarrows} \begin{array}{l} CH_2OCO\,H \\ | \\ CHOCO\,H \\ | \\ CH_2OCO\,H \end{array} + RCOOH$$

It can run from right to left or vice versa, depending on the operating conditions which may modify the equilibrium situations (Karleskind, 1992).
Furthermore, the reaction may take on various specific features if, for example, it occurs in the presence of enzymes capable of activating the various active centres. For example, hydrolysis in the presence of pancreatic lipases leaves the condition round carbon 2 intact but detaches the two fatty acids from positions 1 and 3.

Some lipases, such as those of cobra poison, operate in the opposite direction whereas others distinguish between positions 1 or 3, so that guided hydrolysis and, conversely, specific esterification may occur (Linfield, 1984; Nielsen, 1985; Buhler, 1987).

When the saponification reaction is not complete, a mixture of tri-, di- and monoglycerides and glycerine is obtained but esterification is never complete and substantial quantities of mono- and diglycerides co-exist with the triglycerides at the end of the reaction.

Various catalysts are capable of accelerating the reaction speed in both directions. These are usually Lewis acids. Similarly, the removal of one constituent may determine the direction. For example, the removal of water determines the formation (partial or total) of glycerides while its presence encourages the formation of fatty acids and glycerine. These features are applied in industry to obtain glycerides from esterification and fatty acids from hydrolysis.

The reaction has variations; for example, instead of water, a strong alkali can be used which determines the formation of the corresponding soap (and glycerine). This feature also has industrial applications.

Other reactions of the carboxylic group

In the presence of the right catalysts, triglycerides can react alone, with other oils or other alcohols, changing the position of the carboxylic functions (Karleskind, 1992).

For example, when olive oil is brought into contact with sodium methylate at ambient temperature, the oil is «randomised» and changes the position of the fatty acids with respect to positions 1, 2 and 3, so that a specific analysis will show saturated acids in greater quantities in position 2 than is possible according to the law of natural distribution. In the end, the arrangement of fatty acids will be the same as in esterification. If mixed with another oil and subjected to the same treatment, the fatty acids of one will take the positions of the other, resulting in a mixture of triglycerides with a completely random arrangement of fatty acids.

Finally, the same types of reaction applied to a mixture of oil with an alcohol (ethyl, methyl, etc.) will yield a mixture of esters (ethyl, methyl, etc.) releasing the glycerine.

All these reactions have important industrial applications, both for modifying physical and chemical properties and for producing the intermediate chemicals (esters) used in various branches of industry.

Oil can be transformed into other derivatives, always through reactions directed at ester bonds.

Hydrogenation with special catalysts at high temperatures transforms the fatty acids into primary long-chain alcohols and glycerine (Karleskind, 1992; Rao, 1989).

Purely chemical methods (reduction with sodium and alcohol) can be used for the same reaction (for industrial applications); or catalysts that do not attach the double bonds can be used to form oleic alcohol for use in the cosmetics industry.

The carboxylic group can be salified with ammonia or amines and then dehydrated to yield first amides and then nitriles.

$$\mathrm{RCOOH + NH_3 \longrightarrow RCOONH_4 \longrightarrow RCOONH_2 + H_2O \longrightarrow RCN + H_2O}$$

$$\mathrm{RCN + H_2 \longrightarrow RCH_2NH_2}$$

Nitriles are the point of departure for a series of surface-active products. Amino-alcohols are also used to obtain a number of amides/esters which are used in detergents and cosmetics.

Alkylic chain reactions

The alkylic chain of fatty acids in olive oil can be classified in relation to the number of carbon atoms and double bonds (always in cis configuration) present (Table 2). The number of carbon atoms is between 15 and 23 (excluding the carboxyl carbon); simple double bonds are present in chains of 15-19 members, and bonds with interrupted methylene bridge occur only in chains with 17 carbon atoms.

Naturally, the active points are placed in the methylene group adjacent to the carboxylic group, but more distinctly in groups adjacent to double bonds. The reactivity of such points is evident in isomerisation (Karleskind, 1992), i.e. the reaction which modifies both the appearance of the double bond, and its position (Snyder, 1982; Kohashi, 1989; Cecchi, 1982; Ucciani, 1983; Cecchi and Ucciani, 1984).

The reaction has a low potential barrier so isomerisation reactions often accompany other reactions. For example, partial hydrogenation of any oil and therefore also of olive oil is always accompanied by isomerisation as a secondary reaction.

Hydrogenation is a reaction with a high potential threshold which diminishes its own unsaturation by combining hydrogen and a fatty substance (Karleskind, 1992; Albright, 1985):

$$-CH=CH- \xrightarrow{\text{Catalyst}} -CH_2-CH_2-$$

In spite of the reactivity of the two reagents, only the presence of a catalyst can induce appreciable reaction speeds for the transformation to take place in real time. All hydrogenation catalysts can induce the reaction but in practice, at least in industry, nickel is the most widely used.

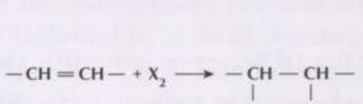
Depending on requirements, it can be used in various forms (subdivided, supported, as salt, etc.), with different effects on the occurrence of isomerisation reactions.

Thus, a hydrogenated olive oil is always accompanied by different quantities of various isomers in the cis-trans position.

Isomerisation may occur every time oil comes into contact with Lewis acids, especially at relatively high temperatures (over 100ºC) and in autoxidation, etc. Just as there is hydrogenation, there is also the reverse reaction, dehydrogenation. Chemically difficult, this reaction is much easier biochemically and may serve to increase unsaturation. There are biological systems which dehydrogenate stearic to oleic, linoleic, and other such acids, and palmitic to palmitoleic acid. Other systems inhibit the same bio-reactions.This may have useful biotechnological implications.

For example, it might be possible to develop varieties having specific fatty acids.

The alkylic chain may cause addition reactions (such as hydrogenation) or substitution. Addition reactions include halogenation (Karleskind, 1992):

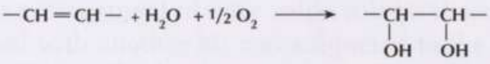


$$-CH=CH- + X_2 \longrightarrow -\underset{X}{CH}-\underset{X}{CH}-$$

This reaction may be used analytically to determine the iodine value and is often accompanied by substitution.
Addition can occur with a certain number of reagents, such as thiocyanogene. This reaction is also used for analytic determination. Another relevant addition reaction is that with ozone. The ozonides obtained can be used for a number of reactions, all due to the chain being broken at the point where the double bond was present (Karleskind, 1992).
Thus, nonanoic and azelaic acid can be obtained from oleic acid, as shown in the following diagram:

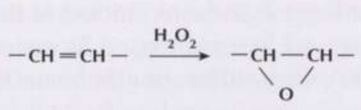
$$CH_3(CH_2)_7-CH=CH-(CH_2)_7COOH+O_3 \xrightarrow{+O_2} CH_3(CH_2)_7COOH+HOOC-(CH_2)_7COOH$$

Similarly, nonanoic and azelaic aldehydes can be obtained through the reduction of the ozonide.
Hydroxylation is another apparently addition reaction which can occur with various oxidants as shown in the following diagram:

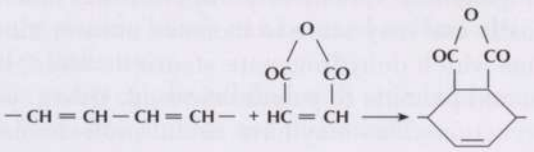


$$-CH=CH- + H_2O + 1/2\,O_2 \longrightarrow -\underset{OH}{CH}-\underset{OH}{CH}-$$

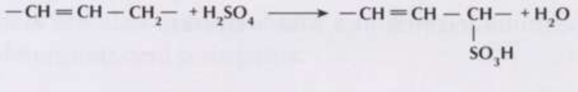
Similar to this is the epoxydation reaction, usually conducted with peracids, which leads to the formation of a 3-member ring (Karleskind, 1992):



The reaction with maleic anhydride yields cyclic compounds but only when the bonds of the alkylic chain are connected, as in isomerisation (Karleskind, 1992; Mattil, 1962):



Substitution as well as addition reactions are behind the sulphatation which occurs when an oil or fatty acid is treated with concentrated sulphuric acid.
The basic reaction (Mattil, 1962) is as follows:



$$-CH=CH-CH_2- + H_2SO_4 \longrightarrow -CH=CH-\underset{SO_3H}{CH}- + H_2O$$

This reaction is used in industry to produce surface-active products which are specifically suitable for the treatment of leather or furs, both in acid form and as alkaline salts.

With liquid sulphuric anhydride, it is possible to substitute a hydrogen in a position adjacent to the carboxyl, to form compounds which isomerise to α-sulphur derivatives, generally used as methyl esters in detergents.

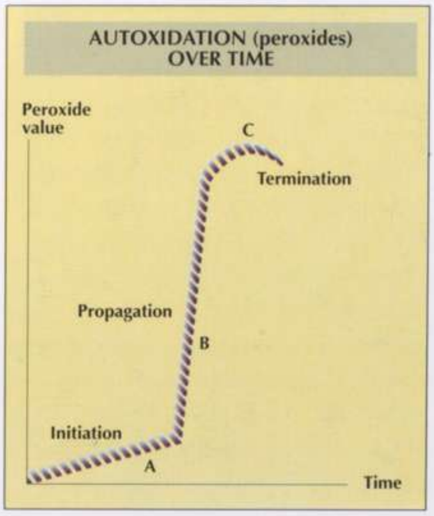


FIGURE 1. Autoxidation (peroxides) over time.

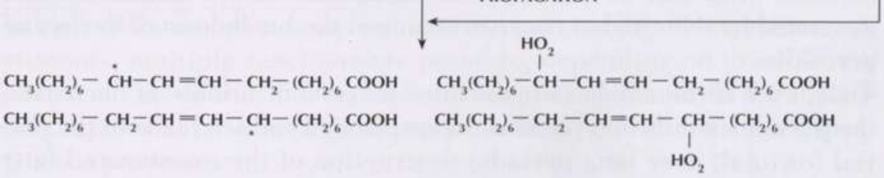
Autoxidation

Autoxidation refers to a set of reactions that start off with the addition of atmospheric oxygen to a fatty acid by spontaneous substitution. The reactions then proceed in a fairly complex manner to rancidity (Lundberg. 1961, Frankel 1984, Gunstone 1984).

They can be defined as chain reactions and are characterised by incremental factors greater than 1.

Even though the phenomenon pertains primarily to active centres adjacent to double bonds, it can also occur on the carbon adjacent to the carboxyl group in saturated fatty acids.

The initial chain is based on the activation of one of the active centres adjacent to the double bonds or to the carboxylic group, in saturated fatty acids. Activation can also be caused photochemically (in ultraviolet) or using other energy or chemical means:



Two different radicals can be formed from oleic acid, which then react with oxygen.

The peroxide radicals remove a hydrogen atom from an intact molecule, generating two new radicals and 2 relatively stable compounds, the peroxides.

Because the formation of the 2 compounds is always active, the initial reaction is added to it so the number of radicals involved is practically doubled.

The first 2 phases of the autoxidation reaction are initiation and propagation and they are followed by a third, erroneously called «termination» (Figure 1). There is a close link between the peroxide content (generally measured as the number of peroxides) and time during the first two phases. The initiation phase is hindered by a certain number of substances called anti-oxidants which block the path, either by acting on the radicals (quenching) or becoming oxidised usually by forming their peroxides which are generally more stable because they are stabilised by resonance. Obviously the anti-oxidant function is eventually exhausted but while it is active it determines what is commonly defined as the induction period.

A typical autoxidation curve is given in Figure 1.

As will be seen below, in addition to anti-oxidants of the tocopherol category, olive oil also includes a series of simple or complex phenolic substances which act as anti-oxidants themselves, or bring about the action of the tocopherols.

In addition to the presence of anti-oxidants which determine the length of the initial line, the acid composition has a decisive impact on the phenomenon. In fact, there are big differences in the autoxidising capacity of the fatty acids.

When saturated acid is 0, the mono-unsaturate is at level 1, the di-unsaturate is 2, and the tri-unsaturate 3; in practice, the di-unsaturate is oxidised at double the speed of the mono-unsaturate, and so forth. All this has an impact on all three phases of autoxidation, reducing the induction period, increasing the slope of the propagation line and modifying the termination phase.

The greater the oleic acid content, the less liable the oil is to oxidation, as long as the amount of saturated acids remains equal. This is clearly the case with olive oil in comparison with other vegetable oils.

The stability of peroxides is relative and they begin to break down almost as soon as they have formed, depending on the oil temperature. The transformations are rather complex, but there are two main aspects:
a) the peroxide behaves as an oxidant, in so far as it is oxygenated water;
b) the peroxide is transformed into other products.

These aspects are present in the termination phase and co-exist with the other two phases even when the termination phase has already commenced. They also co-exist with the connection of the various radicals generated by their higher concentration and the breakdown of the hydroperoxides.

Thus, even if the number of peroxides remains invariable or decreases, the phenomenon is in a phase of intense activity which leads to the partial (or total, over long periods) destruction of the unsaturated fatty acids.

This phase is perceptible to the human sense of smell or taste, and is defined as rancidity. Although the phenomenon varies considerably depending on the type of oil, the circumstances and the oil's background, it may nonetheless be stated that rancid oil contains:

- Volatile matter of an aldehydic or ketonic nature, usually unsaturated; it comes primarily from the oxidising action of the peroxide on the unsaturated fatty acids and has a low number of carbon atoms;
- Compounds with a hydrocarbon structure, unsaturated and poly-unsaturated and usually connected, which come from transpositions; those with a higher molecular weight are formed by the coupling of the alkylic radicals;
- Fatty acids of the original length but with ketonic and hydroxylic functions, bound to the triglyceride molecule;

- Alcohols, usually unsaturated and connected, formed by the same mechanisms;
- Polymers of fatty acids, with Carbon-Carbon, Carbon-Oxygen, Oxygen-Oxygen linkage points, bound to the triglyceride molecule;
- Fatty acids with aldehydic, ketonic and alcoholic functions, of shorter length than the original ones, bound to the triglyceride molecule.

The result is a highly complex structure that is not easy to analyse because of the variety of chemical components.

In the presence of other substances such as foods when cooking (other than oil), the structure may change radically as a result of interactions with the foods and their breakdown products and also because of protective or catalytic actions induced by them.

Metals may have a great influence on autoxidising phenomena by acting as transporters of loads in oxidation-reducing phenomena. They are usually already present in oil, either as natural constituents or because they are picked up during processing, but their concentration may increase in the presence of foods.

The presence of chlorophyll may affect oxidation through photochemical phenomena and by transporting oxygen.

Consequently, various phenomena can occur in autoxidation, depending on many variables. The process is influenced most by the acid composition and anti-oxidant content, both of which are important in olive oil.

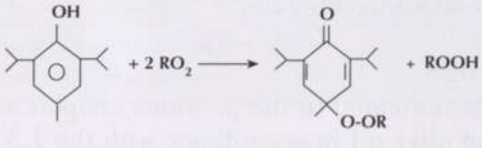
Glycerine reactions

Glycerides consist, in addition to fatty acids, of glycerine in molar proportions of 1:3; for olive oil this corresponds to an average of 10% of the weight of the oil. As already mentioned, this can be obtained from the separation of the oil and can be used for a series of reactions to form various products of great use in industry and in the food sector. Most of the derivatives are obtained from esterification reactions with organic and inorganic acids.

Reactions of the other constituents

In view of the complex composition of olive oil, as regards its minor constituents, multiple reactions are possible, depending on the different chemical classes they belong to. Such reactions can be used for analytical purposes or in technological processes or may result from other spontaneous processes.

An example of the latter is the transformation of anti-oxidants in autoxidation, following the general reaction (applicable to phenolic compounds).



Sterols are present in oils, partly in free form and partly in esterified form. The latter are subject to saponification or, conversely, to esterification (from sterols to esters).

Furthermore, sterols can give rise to a series of reactions such as dehydration, to form cyclical hydrocarbons with conjugated bonds, or isomerization reactions in the presence of Lewis acids acting as catalysts.

Similar reactions are to be found in triterpenic alcohols and methyl sterols.

Olive oil contains a certain quantity of chlorophyll which can participate in autoxidation reactions as a transporter of oxygen. This function, together with the other reactions, especially those of a photochemical type, tends to break it down into its primary constituents, as a result of which the oil loses colour.

The triterpenic diols of olive oil must be mentioned for their capacity to oxidise in the presence of strong oxidants, thus opening ring A which carries two hydroxyls. This obviously makes them disappear, in analytical terms, and they are completely removed by subsequent refining processes.

CHEMICAL COMPOSITION OF OIL

Glycerides represent about 98% of virgin oil, and a little less of pomace oil, if we exclude the free fatty acids, which can represent a high fraction in pomace oil prior to refining.

The free acid content of virgin oil is used to classify it into different categories.

Being a natural product, the chemical composition of oil is obviously variable, at least from the quantitative point of view. It should also be pointed out that many of the biosynthesis reactions which are produced by major and minor constituents are often incomplete or entail collateral deviations which determine the presence of a considerable number of minor constituents. The composition also depends to some extent on soil and climate conditions (Fedeli and Cortesi, 1993). Refining, when applied, can modify composition (Fedeli et al., 1971; Fedeli and Daghetta, 1972). The following description of oil composition therefore refers to virgin oil.

FATTY ACIDS

The fatty acids forming the glycerides of olive oil are given in Table 2. There are considerable quantitative differences, depending on the area of production (Tiscornia, 1977; Paganuzzi, 1974).

Table 3 shows the fatty acid content of olive oils from different countries. In particular, oil from Tunisia is unusual in that it has a higher content of the 18:2 and 16:0 fatty acids and a lower content of 18:1.

There are similar differences in oils from other areas but they tend to be the exception rather than the rule.

TRIGLYCERIDES

The fatty acids indicated in the previous chapter are arranged in the triglycerides of olive oil in accordance with the 1.3 random 2 random rule.

According to this rule, saturated acids occupy the positions which correspond to the primary hydroxyls of glycerine (1.3 considered equivalent), while the unsaturated acids, in addition to occupying the remaining pri-

TABLE 3
THE FATTY ACIDS IN OLIVE OILS OF DIFFERENT ORIGINS
(Paganuzzi, 1974; Tiscornia, 1974)

	ISRL	SPN	TRKY	ARGN	TNSA	ITGR	USA
16:0	12.1	8.4	12.8	15.3	18.6	9.5	5.7
16:1	0.4	0.5	0.7	1.6	2.2	1.5	0.3
17:0	0.1	0.1	0.1	0.1	0.2	0.1	0.0
17:1	0.1	0.1	0.1	0.1	0.2	0.1	0.0
18:0	4.0	2.4	2.3	2.3	2.3	2.4	1.8
18:1	72.3	81.1	71.7	67.0	59.2	76.2	81.7
18:2	10.0	6.7	11.7	13.0	16.6	9.5	10.5
18:3	0.5	0.4	0.2	0.2	0.4	0.6	-
20:0	0.4	0.3	0.2	0.1	-	0.3	-
20:1	0.1	-	0.2	0.2	-	0.2	-
20:0	0.0	-	0.0	0.1	-	0.1	-

ISRL = Israel; SPN = Spain; TRKY = Turkey; ARGN = Argentina; TNSA = Tunisia;

ITGR = Italy-Greece; USA= Estados Unidos.

mary positions, esterify the hydroxyl in the 2-position (Gunstone, 1967; Pulido, 1992; Capella, 1964). This has important analytical consequences which are further described below. The main triglycerides are

TABLE 4
MAIN GLYCERIDES OF VARIOUS OLIVE OILS

ECN	Gly.	TNSA %	SPN %	ITGR %	ECN	Gly.	TNSA %	SPN %	ITGR %
42		1.00	0.19	0.47	46		35.02	17.53	24.43
	MLL*	0.18	0.10	0.04		PLP	1.67	0.12	0.12
	LOT*	0.23	0.13	0.26		MOP*	1.63	0.22	0.69
	LLL	0.44	0.03	0.09		LOP*	12.29	2.93	4.41
44		8.95	2.34	4.40		OMM*	2.25	0.99	2.59
						LOO*	16.96	13.27	16.48
	MOL*	1.26	0.16	0.65	48		49.81	73.68	64.81
	LLP	1.72	0.12	0.27		POP	5.96	1.47	1.77
	TOO*	0.41	0.79	1.04		POO	21.92	17.73	17.68
	LOL*	4.76				OOO	20.16	53.59	44.05
						LOS*	1.52	0.84	1.12
					50		4.19	5.89	5.36
						POS	1.48	0.84	0.90
						SOO	2.72	5.06	4.47

ECN = Equivalent carbon number; Gly. = Glycerides; TNSA = Tunisia;

SPN = Spain; ITGR = Italy-Greece; * = Sum of the isomers.

given in Table 4, subdivided into ECN (Equivalent Carbon Number) categories (Cortesi, 1992; Cortesi, 1990).

They are calculated according to the above rule for the fatty acids listed in Table 3.

MINOR CONSTITUENTS

As already mentioned, olive oil contains an important fraction of minor glyceridic and non-glyceridic constituents. Depending on their structure, the latter at times appear esterified with the fatty acids in the oil (Fedeli, 1977; Mariani, 1993; Mariani, 1991).

TABLE 5.
DIGLYCERIDE COMPOSITION OF EXTRA VIRGIN OLIVE OILS

Oil	Total %	LO %	LP %	OO %	PO %	PP %
S1	1.34	0.02	0.18	0.12	0.82	0.20
S2	1.45	0.03	0.22	0.14	0.87	0.19
S3	1.63	0.08	0.25	0.28	0.82	0.20
S4	2.10	0.07	0.28	0.33	1.15	0.27

L = Linoleic; O = Oleic; P = Palmitic

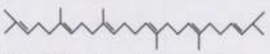
Minor glyceridic constituents

In addition to triglycerides, glycerine is also present in other structures connected to these, in part as a result of enzymatic hydrolysis in the fruit and in part probably owing to incomplete biosynthesis (Cortesi, 1992).
These are the mono- and di-glycerides of the fatty acids in the oil. The diglyceride fraction is higher, and can be analysed to determine the freshness of the product, as the concentration of some of them increases in relation to the quality of the fruit from which the oil was pressed (Cortesi, 1992).
Table 5 gives data on the concentrations.
Unlike in seed oils (40-135 ppm), phosphatides are virtually absent from the minor glyceridic components (Vitagliano, 1960; Vitagliano, 1961; Mancha, 1974).

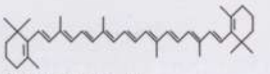
Hydrocarbons, linear and cyclic alcohols

Olive oil contains a series of linear hydrocarbons of the iso and anteiso series (Capella, 1963a), with large quantities of squalene (150-180 ppm). Also present are small quantities of beta-carotene, the biochemical precursor of vitamin A (Tiscornia, 1982).

TERPENIC HYDROCARBONS IN OLIVE OIL



Squalene $C_{30}H_{50}$



β-Carotene $C_{40}H_{64}$

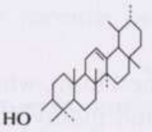
The presence of polycyclic hydrocarbons, although very limited with just a few micrograms per kg, has been the subject of much research (Jung, 1962; Jung, 1963; Jung, 1964; Horward, 1966; Borneff, 1966;

Borneff, 1967; Ciusa, 1965; Ciusa, 1968; Ciusa, 1970; Ciusa, 1974; Ciusa, 1980; Morgante, 1973).

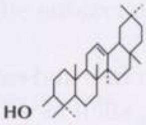
Olive oil contains a series of compounds that probably result from a biosynthetic reaction similar to the fatty acid reactions. These are the linear alcohols with 18 to 28 carbon atoms (Vitagliano, 1976; Camera, 1978; Fedeli, 1977).

A set of particularly interesting compounds are the tri-terpenic alcohols. The most predominant is 24-methylencycloartenol together with cycloartenol and alpha- and beta-amirin (Jacini, 1967; Fedeli, 1966; Fedeli, 1968; Fiecchi, 1966; Fedeli, 1974).

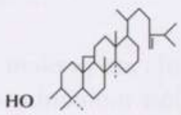
TRITERPENIC ALCOHOLS



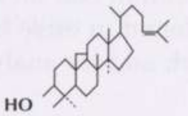
α-Amirin



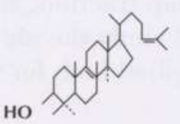
β-Amirin



24-Methylencycloartenol



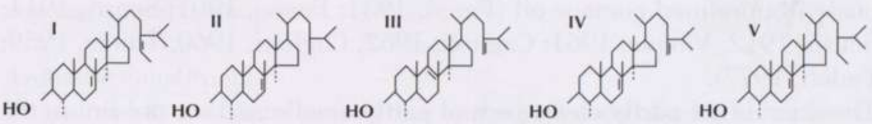
Cycloartenol



Lanosterol

Similar to the first two are the methyl sterols which are probably the result of demethylation:

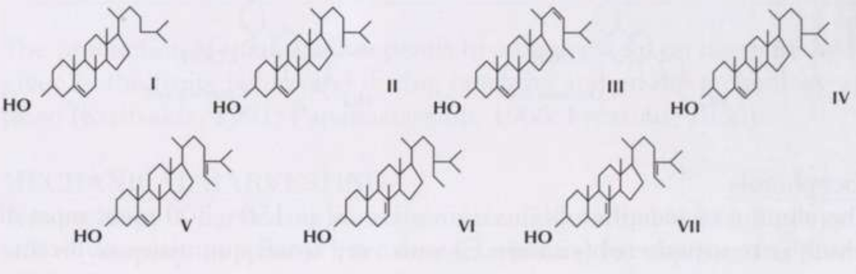
METHYL STEROLS IN OLIVE OIL



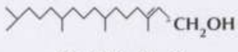
These include obtusifoliol and citrostadienol.

Further demethylation then gives sterols (Capella, 1963; Fedeli, 1966; Fedeli, 1974; Itoh, 1973; Fedeli, 1977):

STEROLS IN OLIVE OIL

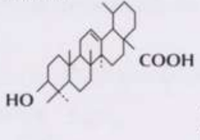


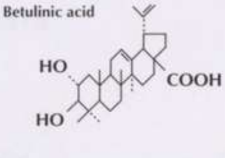
The latter are of particular quantitative and qualitative importance in oil in comparison with all other oils and fats.
Bi-functional pentacyclic triterpenic alcohols include in particular erythrodiol and uvaol which are typical components of the olive epicarp (Kotakis, 1967; Fedeli, 1973; Mariani, 1973).
These are of analytical importance because they are present in small quantities (4.5% of the total sterol fraction) in pressed oils but in very large quantities in solvent-extracted oils (pomace oils) because of their relative insolubility in oil. The terpenic alcohol fraction also includes phytol, probably due to the breakdown of chlorophyll (Jacini, 1967):

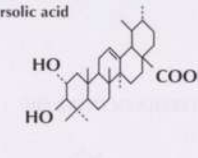

Phytol $C_{20}H_{40}O$

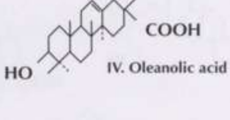
Linear cyclic alcohols are present in both free and esterified form, whereas alcohols with a low molecular weight, such as ethyl and methyl alcohol, which are appreciable in oil, are always esterified (Fedeli, 1972).
After eliminating the soap fraction, saponification can be applied in order to concentrate and study the alcohols found in olive oil. This is generally the method applied both for research and for analytical purposes.
Fractional crystallisation of the glycerides also makes possible the concentration of the fraction for research purposes (Fedeli, 1974).
Combined methods using liquid and gas chromatography and mass spectrometry are often used for the above purposes (Mariani, 1991a, b; Mariani, 1993).

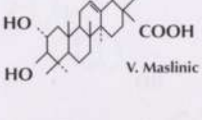
Other terpenic substances
A considerable fraction of terpenic acids is present in virgin oil and obviously in unrefined pomace oil (Parisi, 1931; Peano, 1901; Scurti, 1911; Scurti, 1912; Vioque, 1961; Caglioti, 1962; Caglioti, 1960; Thiers, 1959; Fedeli, 1977).
These acids are partly oleanolic and partly ursolic and are present in the fruit skin from which they can be extracted after removing the oil. The individual constituents:

I. Ursolic acid


II. Betulinic acid


III. Oxyursolic acid



IV. Oleanolic acid


V. Maslinic acid

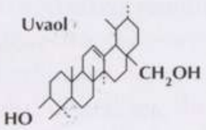
Tocopherols
The content of tocopherols in virgin olive oil is 150 - 300 ppm, most of which is α-tocopherol (vitamin E) with very small quantities of ß-toco-

pherol (Kofler, 1945; Kofler, 1947; Vitagliano, 1958; Bertoni, 1959; Bunyan, 1957; Taufel, 1961; Gracian, 1965; Herting, 1963).
The quantity differs according to the soil and climate conditions in the place of cultivation.

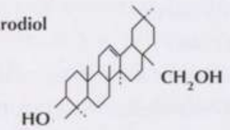
Phenolic constituents
A wide range of phenolic constituents is present in virgin olive oils at different concentrations. They form part of the aroma and are described below togethest with the aromatic constituents.
Of greater importance in view of their characteristics and concentration are tyrosol and hydroxytyrosol and their derivatives (Cortesi, 1977; Cortesi, 1981; Cortesi, 1983; Cortesi, 1985; Fedeli, 1983).
With respect to the derivatives, these are a dense group of esteric chemical substances (esters of the elemolic acid in the alcohols), some of which have recently been the subject of research:

TRITERPENIC DIALCOHOLS IN OLIVE OIL

Uvaol



Erytrodiol



They probably come from the glucosides in the fruit which give rise to oil-soluble aglicones during partial hydrolysis. Subsequent hydrolysis during crushing breaks down the ester bonds and releases tyrosol and hydroxytyrosol which, since they are water-soluble, are partly lost in the vegetable water.
The esters are linked and may be responsible for the bitter, piquant taste of oil but these organoleptic perceptions have not yet been attributed to any one specific compound.

Aromatic constituents
Virgin oil has a distinct aroma due to the presence of a high number of substances that together amount to 250-500 ppm (Fedeli, 1973; Fedeli, 1974; Fedeli, 1976; Flath, 1973; Nawar, 1969; Nawar, 1970). The main ones are given in Table 6. According to Guth and Grosch (Guth, 1991), the main components of the aroma of virgin olive oil are those given in Table 7 with the sensory perceptions they cause.

Transfer of olives.

FROM THE OLIVE ORCHARD TO THE MILL

The production of quality oil depends to a large extent on due care being given to the fruits before and during crushing and on the technology applied (Kiritsakis, 1991; Papanastassiou, 1966; Frezzotti, 1956).

MECHANICAL HARVESTING
The problem of harvesting olives mechanically is that the technology is still developing, in spite of intense research aimed at creating an optimal

Young olive tree.

TABLE 6
VOLATILE COMPONENTS OF VIRGIN OIL

ESTERS

- Aromatic
  - Ethylbenzoate
  - Methylsalicilate
  - Ethylphenylacetate
- Aliphatic
  - Ethylacetate
  - Ethylpropionate
  - Methylbutyrate
  - Ethyl-2-methylpropionate
  - 2-methyl-1-propylacetate
  - Methyl-3-methylbutyrate
  - Ethylbutyrate
  - Propilpropionate
  - Methyl-n-pentanoate
  - Ethyl 2-methylbutyrate
  - Ethyl 3-methylbutyrate
  - Methyl n-hexanoate
  - Methyl n-heptanoate
  - Methyl n-octanoate
  - Ethyl n-octanoate
  - Ethyl n-nonanoate
  - Ethyl n-decanoate
  - Methyl palmitate
  - Ethyl palmitate
  - Methyl oleate
  - Ethyl oleate
  - Methyl linoleate
  - Ethyl linoleate

HYDROCARBONS

- Aromatic
  - Naphthalene
  - Ethylnaphthalene
  - Dimethylnaphthalene
  - Acenaphthene
  - Alkylbenzene
- Aliphatic
  - n-Octane

ALCOHOLS

- Aromatic
  - 2-phenylethane-1-ol
- Aliphatic
  - Methanol
  - Ethanol
  - Methylpropane-1-ol
  - Pentene-1-ol
  - 3-methylbutane-1-ol
  - 2-methylbutane-1-ol
  - 3cis-hexene-1-ol
  - Hexane-1-ol
  - 2trans-hexene-1-ol
  - Heptane-1-ol
  - Octane-1-ol
  - Nonane-1-ol
- Terpenic
  - 1.8 cineole
  - Linalole
  - O terpineole
  - Lavandulole

ALDEHYDES

- Aromatic
  - Benzaldehyde
- Aliphatic
  - sEthane-1-al
  - n-propane-1-al
  - 3-methylbutane-1-al
  - 2-methylbutane-1-al
  - n-butane-1-al
  - n-pentane-1-al
  - 2trans-pentene-1-al
  - 2cis-pentene-1-al
  - n-hexane-1-al
  - 2cis-hexene-1-al
  - 2trans-hexene-1-al
  - n-ephthane-1-al
  - 2.4-hexadiene-1-al
  - 2cis-ephthene-1-al
  - 2trans-ephthene-1-al
  - n-octane-1-al
  - 2.4-heptadiene-1-al (2 isomers)
  - 2trans-octene-1-al
  - n-nonane-1-al
  - 2trans-nonane-1-al
  - 2.4-nonadiene-1-al
  - 2trans-decene-1-al
  - 2.4-decadiene-1-al (2 isomers)
  - 2trans-undecene-1-al

KETONES

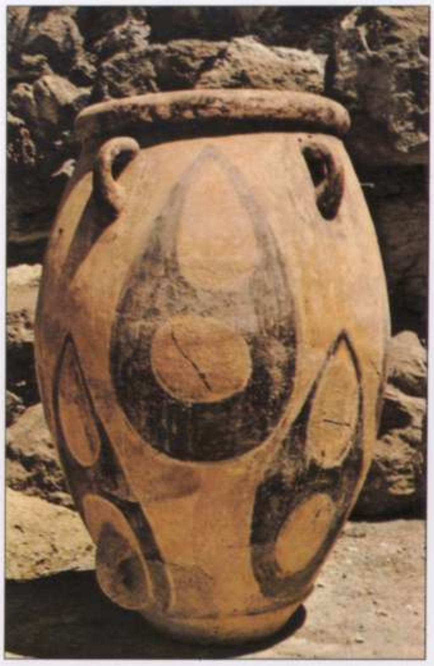
- Aromatic
  - Acetophenone
- Aliphatic
  - Acetone
  - 3-methylbutane-2-one
  - n-pentane-3-one
  - n-hexane-2-one
  - n-octane-2-one
  - n-nonane-2-one
  - 2-methyl-2heptene-6-one

AROMATIC ETHERS

- Methoxybenzene
- 1.2-dimethoxybenzene

TABLE 7
LINK BETWEEN COMPONENTS AND AROMA

Compound	Sensory perception
3-Hexenol	Green leaves
Hexanal	
2-Hexenal	Green, Oily, Bitter
3-Hexenal	Green, Apple
Ethylmethylbutyrate	Fruity
3-hexenilacetate	Fruity
Ethylcyclohexanoate	Fruity
Decadienale	Fried
2-nonenale	Oily
4-methoxy-2 methylbutantiol	Redcurrants


Amphora for storing olive oil from the palace of Phaestos (Crete, Greece).

system (Kiritsakis, 1984; Jacoboni, 1978; Luh, 1975; Fridley, 1969; Fontanazza, 1993).

Harvesting machines are not covered in this chapter which only aims to describe the correct procedure for producing quality oil. In general, such machines are based on the principle of shaking the plants or branches and collecting the fruit in nets. Most of the fruits are collected in the nets but a small amount is not shaken off and has to be picked and, depending on the methods used and the time taken to pick them, these may result in oil of inferior quality. Not all orchards are suitable for the used of such machines, either because of their layout or because of different ripening times. To facilitate the mechanical action, chemical loosening agents can be used although this is not a very widespread practice (Hartmann, 1970; Hartmann, 1976).

MANUAL HARVESTING

Manual harvesting is obviously the most ancient method – some of the fruit falls naturally from the tree and the rest is milked off although, in some places, simple instruments are used to beat the branches.

In all cases, nets are used to collect the olives and prevent them from being damaged.

POSSIBLE DAMAGE TO THE FRUIT

Apart from infestation, the prime cause of damage to olives, it is important to remember that to prepare quality oil the fruit must be in perfect condition.

Abrasion, especially when the olive falls onto the ground, causes a series of enzymatic actions, which tend to alter the oil inside the cells. In particular, hydrolysis and enzymatic autoxidation reactions have been detected, as well as the presence of micro-organisms, which impair the flavour of the oil. Many types of damage give rise to the so-called defective organoleptic characteristics (Psyllakis, 1980; Martínez Suárez, 1975).

TRANSPORT

Even though no special equipment is required to transport the olives, it is worth bearing in mind that damage can occur in this phase which can also cause these effects.

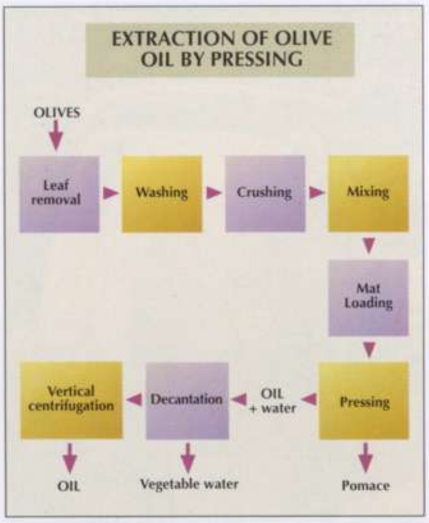


FIGURE 2. Extraction of olive oil by pressing.

Both damage to the fruit and any delay in crushing may affect the quality of the resultant oil.

In particular, care must be taken to avoid bulk transport, and instead to use containers in which the olives can be laid in relatively thin layers (about 25 cm).

CONSERVATION OF THE FRUIT

The enzymes in the fruit can lead to two main actions – one hydrolytic and one oxidative, due to the presence of lipases and lipoxidases in a highly aqueous environment.

Hydrolytic action usually prevails over oxidative action for reasons relating to the carrying of oxygen inside the fruit which increases once the fruit has been damaged.

As the above actions may affect the quality of the oil obtained, there are two decisive factors that must be taken into account. The first is damage to the fruit: when the cell walls are broken, the oil comes into contact with enzymes and oxygen is provided through contact with the air. Enzyme systems apart from those of the olive may be present as a result of contact with the soil giving rise to the development of microorganisms. The second factor is obviously the time of conservation of the fruit which tends to prolong these phenomena.

Generally speaking, alterations affect the organoleptic qualities more than the chemical qualities. In any case, it is preferable to preserve olives not in bulk but in aired containers in layers about 25 cm. thick.

Any other type of conservation (in water solutions, with various treatments, in an inert atmosphere, under refrigeration) is inappropriate, partly for technical reasons and partly for reasons of cost, but especially because it would impair quality.

OIL MILL EQUIPMENT

Basically, the production of any kind of vegetable oil entails rupturing the cells to enable the oil to flow out and to coalesce in larger drops. In olive oil technology, this principle has certain special aspects and involves a number of difficulties owing to the structure of the fruit and the

Primitive oil mill.

considerable quantity of oil it contains. The mechanical actions required may also have an effect on final quality (Figure 2).

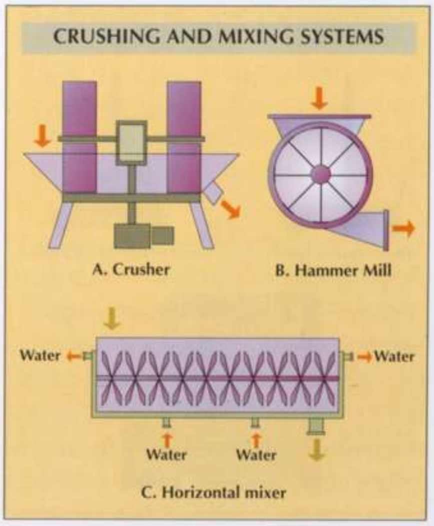


FIGURE 3. Crushing and mixing systems.

WASHING

This operation is important for the elimination of foreign matter from the plant (leaves, stems, etc.) or from the ground (soil, etc) and of any residue remaining from bio-pharmaceutical treatments (Figure 2).

The quality of the water is obviously important. Detergents are not to be used, even if they could prove useful from certain points of view, because it may be difficult to eliminate them completely.

CRUSHING

Crushing is important in both chemical and physical terms because it brings the oil, hitherto protected inside the cell, into direct contact with the other constituents of the cell and the fruit (including enzymes).

In the past, the operation was carried out with a system of wheels rotating around a basin containing the paste; a rudimentary feeding system was used to mix and transport the paste (Figure 3).

The equipment was traditionally made of stone but this has gradually given way to metallic structures, which are not always beneficial for the quality of the final product.

Hammer mills can also be used but, although they are practical and economical, they have a number of drawbacks (Figure 3).

Important transformations can take place during crushing, especially at the expense of those constituents that are more labile than hydrolytic enzymes. For example, certain bitter or pungent principles undergo hydrolysis which improves the quality of the oil if the operation is carried out in such a way as to avoid other, more intense hydrolytic actions.

The exact duration of crushing needs to be determined by testing since it differs for each type of olive. Hydrolysis of the glucosides is necessary if the phenols are to become soluble (minor polar constituents).

These same aspects are present in the subsequent mixing which aims to even out the paste and to cause the minute droplets of oil to coalesce into larger drops, which are obviously less prone to enzymatic attack.

In both phases, the operating times are decisive for the quality of the oil, and must be adapted according to the fruit and in line with previous experience.

When the temperature is raised during mixing (through heat exchange with hot water), oil yield increases: the maximum temperature is 25-30ºC. Most mixers basically comprise slowly rotating blades (20 rpm) inside a metallic cylinder.

In all these processes, there may be metal contamination and this tends to increase the content of pro-oxidants (chiefly iron).

PRESSING

The constituents can be separated from the paste by several means, as indicated below, of which the most ancient is the press (Moreno Martínez, 1964; Petruccioli, 1975; Di Giovacchino, 1988).

Preparation for extraction by pressing

The process comprises several phases. It is basically mechanical, costly from the point of view of manual labour and may lead to contamination if

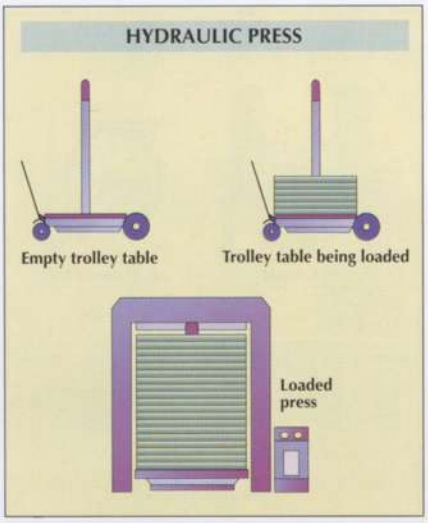


FIGURE 4. Hydraulic press.

the environment is not kept immaculately clean. In practice, modern presses operate on a pile of layers of paste laid between mats that used to be made of plant material such as coconut fibre but are now made of nylon.

The prepared pile is subjected to hydraulic pressure gradually reaching 400-500 Kg/cm^2. The oil and water flow either from the sides of the pile or down the central pole (Figure 4).

After pressing, the pile is dismantled, the pomace removed and the mats are reloaded with the next batch of olives.

The oil which flows out of the presses can be separated by spontaneous decanting or by centrifugation in vertical centrifuges which separate the vegetable water from the oil.

Depending on the degree of separation, the appearance of the oil can range from perfectly limpid to turbid to meet customer preferences.

The presence of particles in the oil means that the oil will be less stable and more prone to rancidity owing to the enzyme load.

Conservation and storage

Once the vegetable water has been removed, the oil is usually preserved for a certain period of time, especially where production centres have a high capacity.

In the case of virgin oil that is to be sold as such, conservation is of importance in order to keep the quality of the oil intact so that appropriately high prices can be asked.

Although olive oil is the vegetable oil with the best keeping qualities thanks to its acid composition and its anti-oxidant properties, this period of conservation is not infinite, especially as regards the organoleptic qualities, and a number of rules must be observed.

- The storage temperature must be kept relatively low by using systems preventing the oil from heating up without requiring refrigeration systems. The optimal temperature is between 15 and 25ºC.
- The absence of residual vegetable water which, together with the enzyme load, may influence the aromatic constituents in particular.
- The absence of radiation, in particular ultraviolet rays: these cause the formation of radicals which initiate autoxidation reactions.
- The containers must be made of unalterable material. Food-quality stainless steel is suitable for the purpose, as is isovitrified iron. Plastic coatings on steel must not be used.
- The containers must contain a limited amount of air and must be moved as little as possible.

  In fact, most oxidation phenomena occur on the surface of the air/oil interface to a depth of about 10 cm.

  Once the available oxygen has been consumed, if not renewed by stirring the oil, oxidation on the layer below 10 cm ceases almost completely and protects the rest of the oil (Fedeli, 1975).

  Thus, the need to ventilate the oil as little as possible must be borne in mind during loading for storage. The same recommendations apply for the preservation of small quantities, and by extension to bottling.

EXTRACTION BY CENTRIFUGATION

The use of centrifugation to extract oil from olives is a relatively recent technique based on the difference in specific weight of the oil, water and

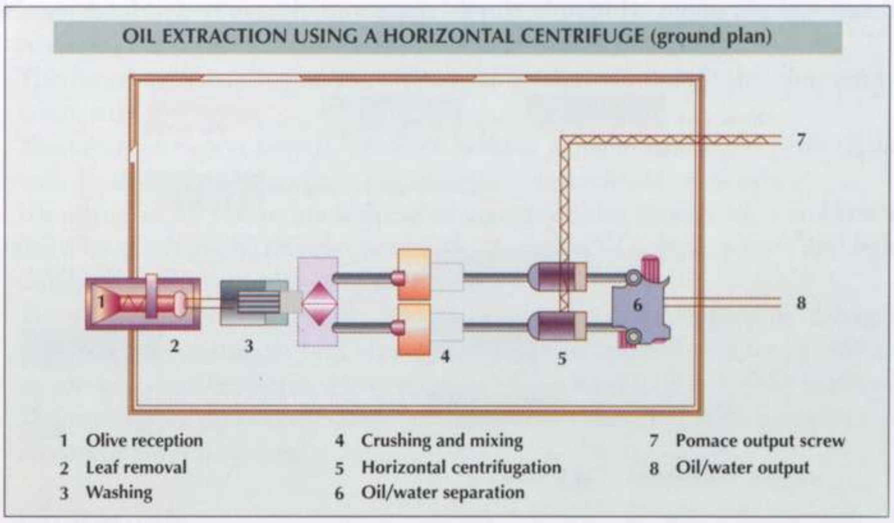


FIGURE 6. Oil extraction using a horizontal centrifuge (ground plan).

pomace. It usually takes place in a horizontal drum rotating at high speed (Fedeli, 1977; Kiritsakis, 1985).

A diagram showing the centrifugation process is given in Figures 5 and 6 although changes are constantly being introduced in an effort to improve its already remarkable efficiency.

The main advantages of this method are that it is both practical and continuous.

In practice, following the conventional method for the preparation of the paste, a relatively large quantity of hot water (50°C) is added to the paste.

The decanter (or centrifuge) continuously separates the pomace which still contains oil and water, from the oil/water and water/oil mix. Centrifugation of the latter two mixes effectively separates the oil from the water.

Technical improvements may eliminate the need to add water, thereby reducing the quantity of effluent.

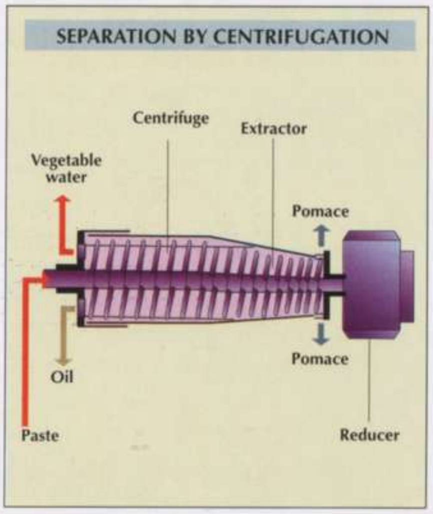


FIGURE 5. Separation by centrifugation.

SELECTIVE FILTERING

In theory, the principle is quite simple and is based on a system which lets oil filter through while holding back the water (Figure 7).

It is, however, complicated to apply in practice. The system basically comprises metal sheets to which the oil drops adhere so that they can be extracted from the paste.

Because the actual drainage of oil from paste is difficult to achieve in practice, the system may be coupled to a centrifuge (Figure 8).

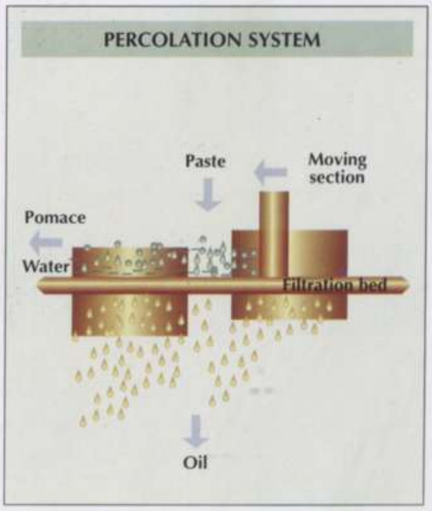
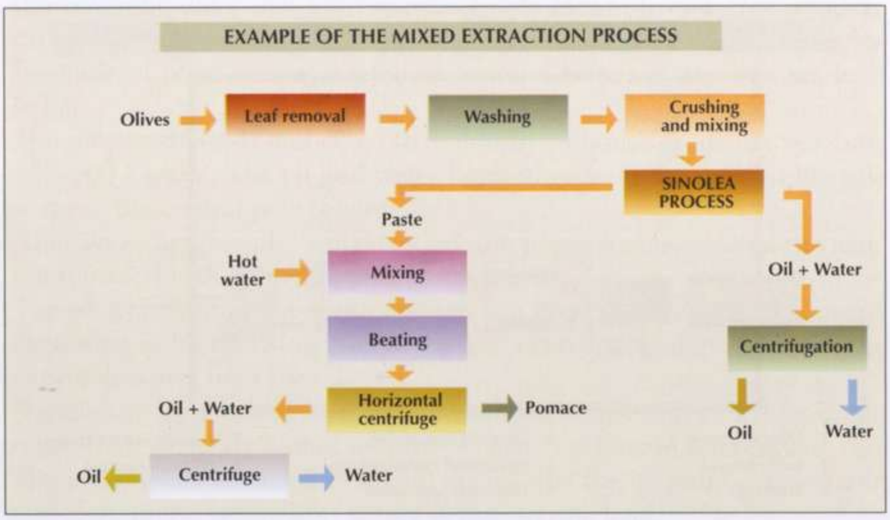


FIGURE 7. Percolation system.

CHARACTERISTICS OF VIRGIN OIL

The chemical and physical characteristics of virgin olive oils are extremely distinctive and can be determined by a series of measurements taken by methods developed and constantly updated to take into account the most recent technological advances. The objective is essentially to ascertain the authenticity of the product, defend it from adulteration, and ascertain its quality.

FIGURE 8. Example of the mixed extraction process.



This section deals only with general aspects; all strictly analytical aspects are dealt with under Analytical methods (p 284).

Oil derived from olives is undoubtedly an authentic product but its quality may vary depending on many parameters as described under Oil mill equipment (p 270) such as the freshness of the fruit, the right degree of maturation and the accuracy of the processing which should be highly reliable if the equipment is properly maintained.

If, for example, the olives are left on the ground for long periods, the glyceridic and minor constituents of the oil may be affected.

An oil that has undergone this type of transformation, especially if related to the sterol content, would no longer be considered authentic because the transformations change the analytical parameters on which authenticity is based.

Refining, which is usually necessary in such cases, cannot restore the oil's authenticity. The limits set have to be maintained if the concept of authenticity is to be valid.

These considerations also apply to other concepts such as the loss of natural anti-oxidants, which is massive under the conditions described above.

Therefore, it can be said that the problem of proper technology, in the widest sense of the term, is important for both authenticity and quality.

ORGANOLEPTIC CHARACTERISTICS AND BLENDING

The final quality of an olive oil may also depend on factors not related to production. For a number of agricultural, climatic and other reasons, oils may vary considerably in terms of taste, to mention only positive aspects and not alterations.

Obviously, the typical features of an oil from the organoleptic point of view may be considered desirable by certain sectors of consumers but such features may not be what consumers in general want. On the contrary, they may prefer flavours that cannot be considered 'typical'. So, especially with virgin oil, the product should satisfy the specific demands of large groups of consumers.

This is achieved by combining oils of various origins, not only to meet organoleptic demands but also to achieve the right price. It has never been established exactly how such blends should be made nor has much research been carried out on the subject.

The large industrial concerns employ specialists to match the characteristics with the price.

The work of expert tasters involves certain aspects that have little to do with analytical testing of the organoleptic characteristics of oils.

Blending is therefore something of an art which, moreover, involves a third factor, namely, the characteristics peculiar to a certain year and to a number of different places of origin.

The work of blending usually results in oils that are accepted by the target group of consumers but, since there is no scientific basis for the interaction between the various components of the aroma, it is a risky process and may cover up certain tastes or reduce the resistance of the product to environmental damage.

PACKAGING

The subdivision of a virgin oil into blends suitable for consumption is risky, especially when long-term conservation is desired (a minimum of one year after production).

Oils, and especially virgin olive oils, are extremely sensitive to external agents, as already indicated under Glycerine reactions (p 261), and in particular to UV radiation which may alter the oil composition and break down the chlorophyll, thus changing the colour of the product.

Consequently, the first precautionary measure is to ensure that the type of containers and the packaging are suitable. Because small quantities are usually packaged in glass bottles, these must be selected carefully for permeability to light or special protection must be provided, as with non-transparent cans.

Another aspect which does not receive much attention is the solubility of atmospheric oxygen in oil (Fedeli, 1975a, b).

In view of the fact that this is 35 ppm regardless of the presence of other gases such as nitrogen, the packaging should be designed to hold much less than the maximum amount of air and special care must be taken when decanting.

The absolute quantity of oxygen inside the packaging is a decisive factor in conservation, oxygen being the main component of the air pocket between the seal (presumably hermetic) and the surface of the liquid.

Various types of bottle.

EXTRACTION OF OIL FROM OLIVE POMACE

Once the mechanical oil extraction operations have been completed, a certain quantity of oil and vegetable water still remains in the solid part (skin + stones + pulp).

Even though the various mechanical and technical systems may obtain different values of residual oil in the pomace, in general, it makes economic sense to recover the oil, especially when ecological considerations concerning the waste are taken into account.

This oil is extracted by applying a solvent to the dried pomace.

Although various solvents (carbon disulphide, triethylene, alcohols) have been used in the past, today virtually all plants operate with hexane for a number of technical, economic and quality reasons.

Because of its apolarity when dry, unlike other solvents, hexane selectively extracts lipid matter, leaving most of the undesired constituents in the exhausted pomace.

Because it is very humid, has a high enzyme content and the constituents have been broken down, pomace is the ideal place for hydrolysis and oxidation phenomena, unless it is quickly dried or extraction takes place immediately.

For these reasons, pomace oils are often high in oxy-acids and in general have high acid levels which at times make the inevitable refining process difficult.

CHARACTERISTICS OF OLIVE POMACE

Olive pomace contains on average 5-8% of residual oil with 25-55% of vegetable water, the rest being solid matter; when dry, the average composition of fresh pomace (A) and of exhausted pomace (B) is as follows (Carola, 1964; Carole, 1975; Bernardini, 1987):

	A	B
OIL	6 - 9	0.1 - 0.3
STONE	42 - 54	9 - 11
SKIN	10 - 11	20 - 22
PULP	21 - 33	10 - 15

The composition of exhausted pomace is:

LIPIDS	0.1 - 0.5
PROTEINS	5 - 12
NON-NITROGEN EXTRACTS	87 - 80
ASHES	5 - 8

EXTRACTION TECHNOLOGY

The wet pomace is transported by conveyor belt systems to the drying installations (usually rotating ovens) in which the hot air is sometimes produced by burning exhausted pomace.

Cyclone and filter systems are used to filter the outgoing air. The dried solid matter (5-8% residual humidity) is conveyed to the extractors, which are essentially of two types, semi-continuous or continuous. In continuous extractors, a series of cylinders receives the pomace in such a way as to form a filtration bed which is then sprayed with solvent (Figure 9).

Usually, there are at least four extraction cylinders, of which one is for loading and one for unloading.

The solvent is drained off from the unloading cylinder by being distilled with steam, after which unloading proceeds automatically.

The solvent/oil solution is conveyed for distillation whereby the oil and solvent are recovered separately. The latter returns to the circuit.

A 4-extractor system can handle about 10 tonnes of pomace a day.

Continuous extractors using buckets or percolation systems, similar to those used for seed oils, are also available but are expensive (Carola, 1964; Carola, 1985; Bernardini, 1987; Kiritsakis, 1991).

CHARACTERISTICS OF POMACE OIL

In general, pomace oil is of an intense green colour, with a typical odour. Chemically, it is quite similar to olive oil with respect to acid composition but it has a greater content of unsaponifiable matter (about 3% depending on the extraction system) and free fatty acids (Fedeli, 1977).

BY-PRODUCTS

Apart from the oil which is used as a food product (the refining of which is described further on), exhausted pomace is a usable by-product. Its calorific value is 3500 Kcal/kg, and it can be used as fuel to supply energy to the oil sector and other industries.

The separation of the woody parts (from the stone) from the remainder (pulp and skin) increases the proportion of protein by up to 15 - 18%. Once palletised, the remains are used as animal feed in mixtures with other constituents.

Similarly, the non-protein fraction which contains similar constituents of industrial value can be extracted with polar solvents and then hydrolysed to yield multi-purpose fatty acids and pectin (Lanzani, 1985; Bondioli, 1989).

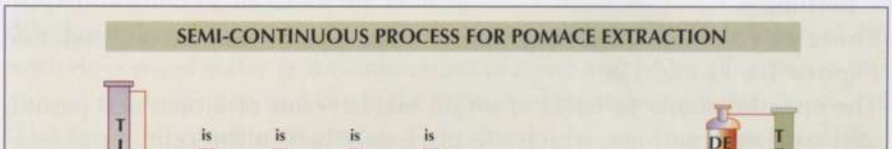


FIGURE 9. Semi-continuous process for pomace extraction.

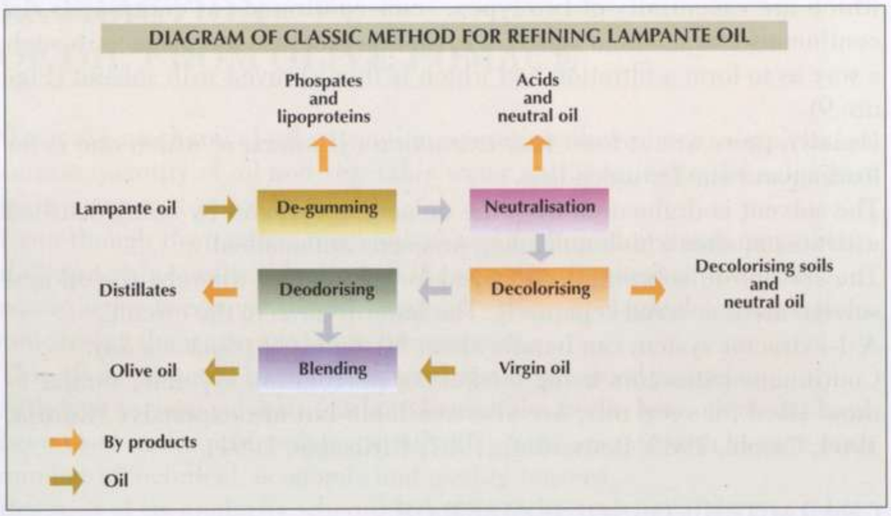


FIGURE 10. Diagram of classic method for refining lampante oil.

FIGURE 11. Diagram of physical refining process.

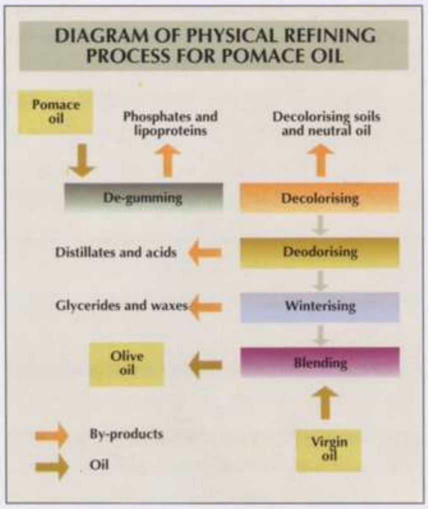


FIGURE 12. Diagram of physical refining process for pomace oil.

REFINING METHODS

Virgin oils not suitable for consumption due to their acidity or organoleptic characteristics as well as pomace oil are refined and mixed with virgin oils in order to produce oils fit for consumption under the designation «olive oils» and «pomace and olive oil».

The two qualities can naturally be distinguished analytically as will be shown in Analytical methods (p 284).

Even though all the methods currently used to refine seed oils and fats are also used for olive oil, the stability of olive oil also allows for the use of the so-called physical processes.

The refining of olive and pomace oil usually entails the same phases as with other oils (Mattil, 1962):

- Removal of gums
- Neutralisation
- Decolorising
- Deodorising
- Winterisation
- Blending
- Bottling

These may be applied all together or some phases may be omitted. See Figures 10, 11 and 12.

The specific characteristics of virgin oil, in terms of aroma and certain anti-oxidant fractions, which are obviously lost in the refining of lampante oils, are partially restored through the addition of virgin oils.

REMOVAL OF GUMS

This operation is intended to remove hydratable impurities (Segers, 1989; Strecker, 1986; Karleskind, 1992) and generally involves the use of organic or mineral acids. The chemical aspects of this operation are different in olive oil and seed oils because of the different quantities of phospholipids and hydratable substances (lipoproteins).

The operation is usually carried out in a discontinuous manner, with the addition of the preselected acid, preferably in concentrated form, while stirring slowly.

Water is then added and the layer of impurities is separated off and, if necessary, centrifuged to diminish oil loss; finally the product is washed with water to remove any remaining residue.
A continuous process can also be used in combination with neutralisation or, if physical refining is to follow, in combination with decolorising.

DE-ACIDIFICATION USING ALKALIS

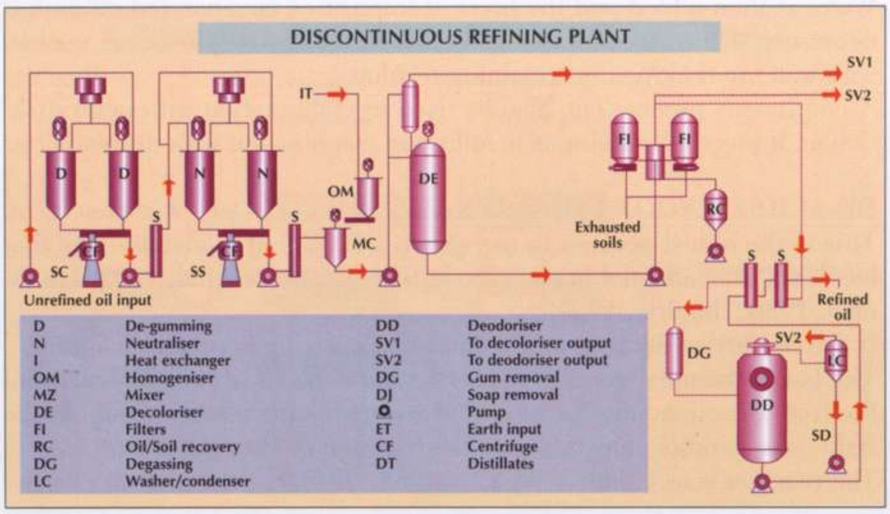
This is the oldest process in use (Mattil, 1962) but is also the one that has been most adapted to meet modern needs (Karleskind, 1992; Linneman, 1986; Hendrix, 1989).
It can be carried out in combination with dewaxing or removal of gums.
The basic chemical concept is simple and consists of the salification of the free organic acidity by means of strong alkalis (caustic soda) at the right concentration depending on the type and quality of the oil.
The reaction is as follows.

$$\mathrm{RCOOH} + \mathrm{NaOH} \longrightarrow \mathrm{RCOONa} + \mathrm{H_2O}$$

The formation of soap makes the free acids insoluble, causing them to separate off into a layer as long as no emulsions are formed which is always possible because of the surface-active nature of the soap.
The reaction is accompanied by a series of collateral transformations which for the most part have a beneficial effect on the quality of the refined oil.
Neutralisation is basically a discontinuous process carried out in cylindrical recipients with a conical base that are kept moving slowly and to which the alkali solution is added.
The recipient also serves as a decanter of the soaps which have formed (sometimes in the presence of an electrolyte, normally sodium chloride); these are removed from the base and, if necessary, centrifuged to recover the oil.
The operation always entails a loss of neutral (measured by the neutralisation coefficient) for mechanical (emulsification) or chemical reasons (saponification of alkali on the neutral).
Washing always takes place in the same recipient, and can be carried out with de-ionised water or a combination of brine and water. The pastes obtained are separated and the olein recovered for industrial uses.
The secondary reactions are:

- Precipitation of heavy metals as hydrates: beneficial because they act as catalysts for autoxidation
- Partial destruction of peroxides: beneficial because the original condition is regained
- Elimination of oxidised substances of acidic nature: also beneficial because the original condition is regained
- Partial elimination of tocopherols. This is not beneficial because it reduces anti-oxidants
- Destruction of anti-oxidants and other labile molecules. Also negative for the same reasons but partly beneficial because it eliminates certain products of oxidation.

FIGURE 13. Discontinuous refining plant.



- Loss of aromas of acidic nature as well as elimination of certain organoleptic perceptions from acid molecules.

The operation is usually carried out at temperatures between 80 and 100ºC, with soda concentrations and quantities proportional to the acidity of the oil.

In order to avoid losses, centrifugation may be used after neutralisation but this is usually expensive and is only applied in special circumstances.

The operation described in Figure 13 is the classic discontinuous neutralisation process still applied by many operators, especially in cases of fairly moderate acidity levels. It can also be applied continuously in plants which use centrifuges fed from mixers, which in turn are fed by dosing pumps, to reach the right proportion of neutralising solution and of oil to be neutralised (Figure 14).

The separation of the soapy pastes and the washing of the oil are carried out as continuous processes.

There are numerous variations of this process, sometimes combining neutralisation with degumming, or including the drying phase in preparation for decolorising (Hendrix, 1989; Gadomski, 1986; Smallwood, 1986; Eaton, 1986).

Another interesting innovation in neutralisation technology combines the alkali treatment with a cooling operation so that the waxes can be absorbed by the soaps formed and then separated off.

For very high acidity levels, which are common in pomace oils, an installation has been introduced, based on two solvents (e.g. isopropanol or acetone and hexane), the most polar of which functions as the solvent of the soda first and then for the neutralisation of the soaps, while the apolar dissolves the oil, first acid and then neutral.

The phases are separated immediately by means of decanting systems which also wash the solutions with the other solvent. In this way, the soaps of the neutral phase are exhausted and the oil contained in the soaps is recovered.

Installations based on this principle were brought into use when energy costs were low.

Both the recovery by distillation of the solvent from the neutral fraction and the recovery of the polar solvent after the separation of the soap

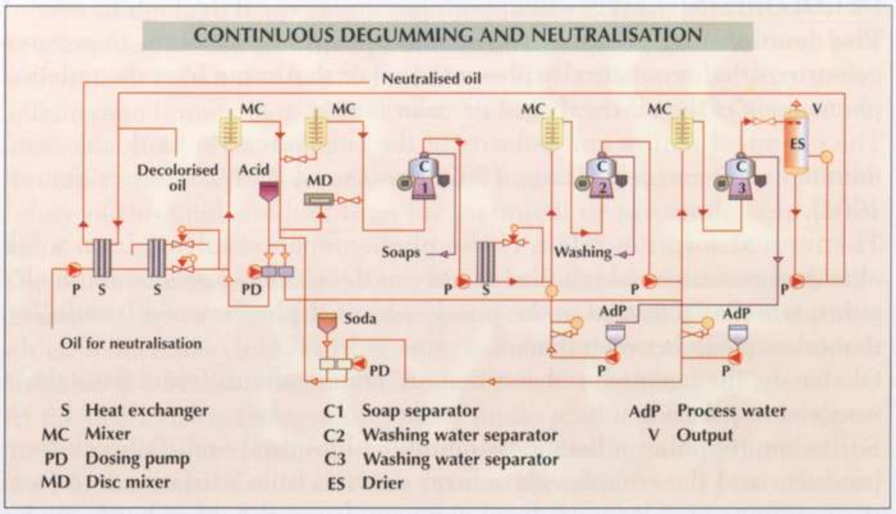


FIGURE 14. Continuous degumming and neutralisation.

phase, as well as the correction of the latter to eliminate the water formed by the saponification and separation reactions, are in fact very costly operations in terms of energy.

PHYSICAL REFINING

As indicated above, the chemical nature of olive oil makes it suitable for physical refining to eliminate volatile substances, at such temperature and residual pressure conditions as to also eliminate the free fatty acids (Stage, 1986; Martínez Suárez, 1986).

The process is basically a physical one and can also be applied when acidity is high.

The oil should first be refined by degumming (already described) and decolorising (described below). These preliminary operations are indispensable to eliminate substances that might permanently alter the colour and taste of the refined oil.

Figures 11 and 12 show how the operation works.

Three variables are involved in the process: temperature, pressure and the time the process lasts.

The lower the residual pressure (generally between 2 and 5 mm Hg), the lower the operating temperature (between 230 and 280ºC) and the shorter the duration of the process. The latter variable also depends on the design of the installation.

Under such operating conditions, a large number of substances will obviously co-distillate with the fatty acids, including the volatile substances generated by autoxidation. This means that the operation is similar to that for deodorising so one step of the classic refining method can be omitted.

For reasons to do with savings but also for reasons of quality in the final product, a certain amount of residual free acids (e.g. 2%) is often left in the oil.

The oil then undergoes chemical neutralisation with alkalis and, in this way, the positive effects of purification as described above are achieved.

The advantages of physical neutralisation include the recovery of the acid fraction to a fair degree of purity so that it is not necessary to separate the saponified pastes.

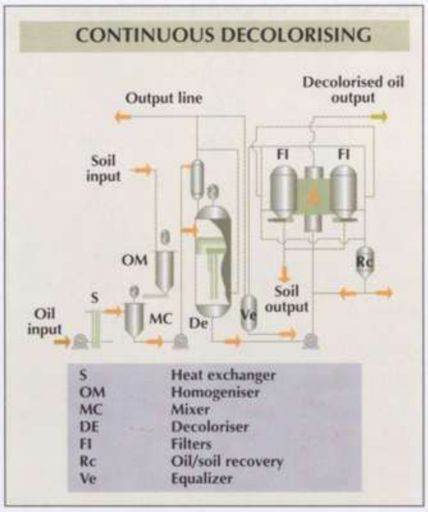


FIGURE 15. Continuous decolorising.

DECOLORISING

The decolorising phase aims, by absorption or partition, to remove colourings that are naturally present in oil or that come from degradation phenomena of the oil itself or of its colorants.

The chemical nature and polarity of the substances to be decolorised therefore varies widely (Maag, 1989; Benjamins, 1989; Martínez Suárez, 1986).

The term absorption refers to the phenomenon resulting from weak chemical reactions taking place between decolorising agents and molecules, whereas partition is the purely physical phenomenon (solubility) that takes place between them.

Obviously, the agents for absorption are chemically different from those involved in partition.

For example, polar substances include chlorophyll and its breakdown products and the complex structures derived from oxidation and from the reactions of certain oxidised compounds; on the other hand, apolar agents substances include carotenes and certain poly-unsaturated hydrocarbons.

The efficiency of the operation can be influenced by selecting, depending on the case, decolorising agents of a polar nature such as active soils (aluminosilicates activated with acids or synthetic silicates) or apolar (usually active carbon), in order to eliminate polar and apolar compounds respectively.

The former type are most commonly used for decolorising, mixed with carbon if required.

The operation is both complex and expensive because the oil from the soils has to be extracted with solvents, and because of waste disposal problems.

For these reasons, technology has been geared to the use of highly effective decolorising agents absorbing minimum quantities of oil, such as synthetic silicates mixed with aluminosilicates.

Decolorising plants, once relatively simple have gradually increased in complexity to become continuous and to meet the requirements mentioned above (Figure 15).

In practice, the operation consists of drying the oil, then mixing it with the decolorising agent. This mixture is then dehydrated and, after a brief contact time (15/20'), subjected to filtering, followed by the recovery of any oil retained.

DEODORISING

Certain aspects of this phase of the refining process are dealt with in the section on physical neutralisation which is based on similar principles.

This operation is used to remove all substances which render the oil unpalatable.

In technical terms, the process can be defined as distillation in a steam current under vacuum (2-10 mm Hg) (Loft, 1986; Stage, 1986; Martínez Suárez, 1986).

The introduction of water vapour at low pressure is indispensable to compensate for the low volatility of the compounds to be eliminated, the steam pressure of which is very low, especially in the final phases.

Deodorisation originated as a discontinuous operation. It gradually became semi-continuous and then continuous, as shown in Figure 16.

In view of the high temperature required (220 - 280ºC), which varies depending on the contact times and the design of the installation, heat transmission is a technical problem which can be solved by using adiathermic liquids in order to avoid the high pressures which are sometimes necessary with vapour.

Recently, these liquids have been used more for reasons to do with the safety of the final product than for technical or economic considerations.

The operation may seem physical, but it includes chemical aspects. For example, the co-distillation steam may initiate hydrolysis reactions which reduce the yield. Furthermore, isomerisation reactions may occur on either the fatty acids or certain minor constituents.

At the deodorising temperature, many labile products such as hydroperoxides are broken down into volatile matter and eliminated by distillation. At the end of the deodorising process the oil is free of peroxides and practically devoid of oxygen.

FIGURE 16. Continuous deodoriser.

DEWAXING

Olive oils left at temperatures below 15ºC deposit a solid layer of glycerides. In pomace oils, the layer contains relevant quantities of fatty acid esters with long-chain alcohols (Tirtiaux, 1986; Martínez Suárez, 1986).

These are the waxes that have to be removed.

The operation can be carried out in various ways, depending on the concentration and the results required.

The most efficient method is by freezing the oil in a solution with an organic solvent (hexane, acetone, etc.), as shown in figure 17.

The operation is carried out at a temperature of 4ºC with an oil/solvent ratio of 40/60. The yield varies in accordance with the nature of the oil and its capacity to form crystalline aggregates which can be easily filtered off.

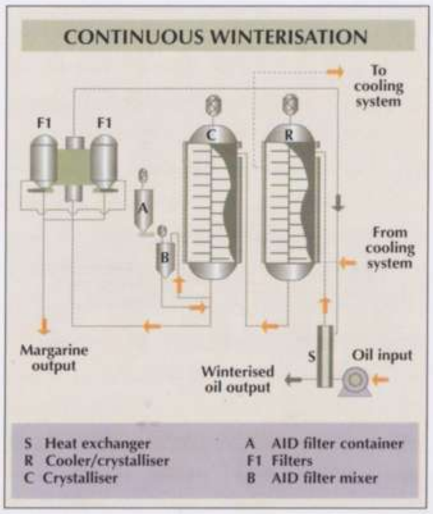


FIGURE 17. Continuous winterisation.

ORGANOLEPTIC CHARACTERISTICS AND BLENDING

Refined olive oils such as pomace oils are usually blended with virgin oil for the purpose of restoring both their resistance to autoxidation and the organoleptic characteristics lost in refining.

The quality and quantity of the virgin oil to be added are determined depending on the characteristics required in the oil by specific markets.

Certain virgin oils may also be added to alter not the taste of the oil but its resistance to oxidation.

BY-PRODUCTS

There is no particular policy for the use of the by-products of refining, and such products have been used for a variety of purposes (Fedeli, 1983).

The first by-product of refining are the gums which can only be used as saponifiable matter together with other residual fats.

Large quantities of soaps are obtained from neutralisation with alkalis and of fatty acids from physical refining.

The former can be used for the production of soaps or, after treatment, with acids to obtain what are known as oleins, a mixture of neutral fats and free acids (an average ratio of 35/65).

These are used to produce what is known as oleic acid, which is used for various industrial products and in a salified form as an emulsifying agent in polymerisation to obtain latex.

A similar use is given to the acids from physical refining which generally have a high free acid content (92-95%).

The fatty cakes left after decolorising are not a very useful residue, in spite of their high oil content. Small, specialised companies extract the fat content using solvents to produce oil for industrial use.

Of interest is the composition of the distillates from decolorising which consist of free acids (30%), glycerides and partial glycerides (10%), ethyl and methyl esters of fatty acids (30%), hydrocarbons, including squalene (20%), alcohols and sterols (10%). This composition is approximate and varies depending on the nature of the oil being refined.

Their potential for various branches of industry notwithstanding, waxes have generally only been used sporadically and for the most part are added to olein.

ANALYTICAL METHODS

As already indicated, the analytical methods used in the oil sector basically aim to determine two aspects, namely, authenticity and quality. Quality control includes the classification of oils.

Such controls are based on an Agreement, reviewed periodically by the International Olive Oil Council, an organisation to which 96% of producer countries belong.

Olive oil is currently classified in the following categories (1993 Trade Standard).

1. Extra virgin olive oil (EVOO)
2. Fine virgin olive oil (FVOO)
3. Semi-fine virgin olive oil (SFVOL)
4. Lampante virgin olive oil (LVOL)
5. Refined olive oil (ROO)
6. Olive oil (OO)
7. Crude olive pomace oil (COPO)
8. Refined olive pomace oil (ROPO)
9. Olive pomace oil (OPO)

The abbreviations given in brackets are used below.

The chemical and physical characteristics of the above categories are given in Tables 8 (and 2, 3) and 9 (2, 3).

The analytical methods used to ascertain the various characteristics are contained in the publications of the IOOC and in the Official Journal of the European Communities, and form part of the national legislation of the producer countries.

Although the data in Tables 8 (and 2, 3) and 9 (and 2, 3) refer to the particular and inseparable characteristics of the various categories of olive oils, there are some that relate to quality and the lack of blends with other olive oils (Table 8 and 2, 3). Others are more specifically geared to ascertaining authenticity, that is, the absence of blends with oils obtained from other botanical species or with soluble organic substances (Table 10). All the methods, and therefore the maximum and minimum values fixed with a view to ascertaining technological methods used to erase evidence of blends, are considered quality or authenticity controls depending on the oil being tested.

TABLE 8
QUALITY CHARACTERISTICS

	A Acidity	B K232	C K270	D K270+	E Delta K	F Panel	G T. N. Perox
1. EVOO	M 1.0	M 2.4	M 0.20	M 0.10	M 0.01	> 6.5	M 20
2. FVOO	M 2.0	M 2.6	M 0.25	M 0.10	M 0.01	> 5.5	M 20
3. SFVOL	M 3.3	M 2.6	M 0.25	M 0.11	M 0.01	>3.5	M 20
4. LVOL	> 3.3		> 0.25	M 0.11		>3.5	>20
5. ROO	M 0.5	M 3.4	M 1.20		M 0.16		M 20
6. OO	M 1.5	M 3.4	M 1.00		M 0.13		M 20
7. COPO	m 2.0						
8. ROPO	M 0.5	M 5.5	M 2.50		M 0.25		M 20
9. OPO	M 1.5	M 5.5	M 2.00		M 0.20		M 15

M = Maximum; m = minimum

TABLE 9
QUALITY CHARACTERISTICS

	H Aliphatic alcohols	I Saturates in pos. 2	L Erythrodiol + UVAOL	M Total sterols (mg/kg)
1. EVOO	M 300	M 1.3	M 4.5	m 1000
2. FVOO	M 300	M 1.3	M 4.5	m 1000
3. SFVOL	M 300	M 1.3	M 4.5	m 1000
4. LVOL	M 400	M 1.3	M 4.5	m 1000
5. ROO	M 350	M 1.5	M 4.5	m 1000
6. OO	M 350	M 1.5	M 4.5	m 1000
7. COPO		M 1.8	m 12	m 2500
8. ROPO		M 2.0	m 12	m 1800
9. OPO		M 2.0	> 4.5	m 1800

M = Maximum; m = minimum

QUALITY CONTROLS

These are the analytical methods used and the limits set to:

- Classify oils in the appropriate category
- Identify blends with olive oils of other categories
- Identify blends with oils other than olive oils and technological practices intended to conceal blends

Table 8 provides data on acidity which are fundamental for defining the category of an oil; the spectrophotometric characteristics, which also indicate oxidative phenomena as well as any blends with other olive oils that have undergone refining or treatment to alter such characteristics; K 270* is the measurement for oils treated with alumina to separate the oxidative phenomena from the others.

F is the measurement which corresponds to the assessment of the organoleptic characteristics by a tasting panel.

TABLE 10
AUTHENTICITY CHARACTERISTICS, STEROLS

	M Cholesterol %	O Brassicasterol %	P Campesterol %	Q Stigmasterol %	R Beta-sitosterol* %	S delta7-stigmasterol %
1. EVOO	M 0.5	M 0.2	M 4.0	< CAMPEST	m 93.0	M 0.5
2. FVOO	M 0.5	M 0.2	M 4.0	< CAMPEST	m 93.0	M 0.5
3. SFVOL	M 0.5	M 0.2	M 4.0	< CAMPEST	m 93.0	M 0.5
4. LVOL	M 0.5	M 0.2	M 4.0		m 93.0	M 0.5
5. ROO	M 0.5	M 0.2	M 4.0	< CAMPEST	m 93.0	M 0.5
6. OO	M 0.5	M 0.2	M 4.0	< CAMPEST	m 93.0	M 0.5
7. COPO	M 0.5	M 0.2	M 4.0		m 93.0	M 0.5
8. ROPO	M 0.5	M 0.2	M 4.0	< CAMPEST	m 93.0	M 0.5
9. OPO	M 0.5	M 0.2	M 4.0	< CAMPEST	m 93.0	M 0.5

M = Maximum; m = minimum; * see text

The peroxide value gives a relatively reliable measurement of alteration due to oxidation.

The limits given in Table 9 are more specifically geared to detecting adulteration. The concentration limit of linear alcohols is fixed at the values indicated to prevent the addition of both virgin and refined pomace oil.

More appropriate for this purpose is the measurement of the wax concentration, another specific constituent, together with erythrodiol and uvaol, of solvent-extracted oil.

The alcohols and wax tests are useful when the two triterpenic constituents that point to pomace oil have been destroyed by chemical oxidation.

The measurement of total sterols makes it possible to identify adulteration aimed at eliminating the non-saponifiable matter, and especially the sterol fraction, by various technological methods, in order to make it impossible to recognise the adulterating agent.

In the case of pomace oil, this is not a matter of authenticity but of quality.

The esterification of oleins obtained from the refining of olive oil has long been used for both recovery and adulteration. In addition to specific fatty acids, various mixtures which simulate the acid composition of the olive oil have been used.

This practice, long forbidden, can be detected if used for adulteration purposes by determining the percentage of saturated fatty acids in the 2-position of the glyceride.

Glycerides naturally follow the law of 1.3 random 2 random according to which there are no saturated acids in the 2-position. However, in esterification, when the acids in the 3-position of the glycerine are redistributed, this leads to a concentration of about 16% of the saturates in the 2-position.

Finally, the data given in Table 11 are mostly historical markers that are no longer used for analytical purposes although some still have commercial value, especially in contracts.

TABLE 11
OTHER CHARACTERISTICS

	Saponif. value mgKOH/G	Iodine value (M. WIJS)	Unsaponi-fiable g/Kg	Moisture & volatile matter %	Impurities (Hexane) %
1. EVOO	184-196	75-94	> 15.0	M 0.2	M 0.1
2. FVOO	184-196	75-94	> 15.0	M 0.2	M 0.1
3. SFVOL	184-196	75-94	> 15.0	M 0.2	M 0.1
4. LVOL	184-196	75-94	> 15.0	M 0.3	M 0.2
5. ROO	184-196	75-94	> 15.0	M 0.1	M 0.05
6. OO	184-196	75-94	> 15.0	M 0.1	M 0.05
7. COPO	182-193	75-92	> 25.0	M 0.5	
8. ROPO	182-193	75-92	> 25.0	M 0.1	M 0.05
9. OPO	182-193	75-92	> 25.0	M 0.1	M 0.05

Relative density 20C/200, 910-0, 916

Refraction index nD 20C, Virgin and refined oils 1.4677-1.4705

Refraction index nD 20C, Without refined oil 1.4680-1.4704

M = Maximum

AUTHENTICITY TESTS

Some of the tests described above (I, M) are also suitable for ascertaining authenticity. It is necessary to add to them the limits relating to the analytical methods given in Tables 10 and 12. The limits for sterols are of special importance, because the composition of the sterol fraction in olive oil is specific and peculiar to olive oil owing to the high content of b-sitosterol and the absence of sterols with bonds in delta-7 (ring b of the sterol structure).

b-sitosterol is in turn a mixture of various constituents that cannot be separated using conventional chromatography techniques, but only with capillary columns; their relative percentages are given in Table 10, together with other constituents that this type of chromatographic method is able to detect.

Table 12 shows the trilinolein limit to detect blends with non-olive oils.

The concentration of linoleic acid in olive oil does not allow it to form this glyceride, except in small quantities.

However, some oils, such as those from Tunisia, which are particularly rich in this acid, may exceed the limit.

For this reason, and because most virgin oils have triolein values closer to zero than to the fixed limit, a comparison is recommended between the theoretical figure obtained by calculations based on the law of distribution of fatty acids in natural oils (1.3 random 2 random) and the value obtained experimentally.

Table 12 also gives the limits for minor fatty acids, but not the intervals for the major components because, since the latter are fairly wide, for the purpose of ascertaining authenticity, it is more appropriate to compare the concentrations of these limiting acids.

Differences of separation also exist in the case of fatty acids, depending on whether conventional or capillary GLC columns are used. Methods based on the latter make it possible to measure the concentration of isomers (trans, cis/trans, trans/trans etc) formed by the drastic treatments

TABLE 12
AUTHENTICITY CHARACTERISTICS, GLYCERIDES AND FATTY ACIDS

		T	U	V	W	Z	X Y
	Trilinolein	Myristic	Linoleic	Arachic	Eiconoic	Behenic	Lignoceric
		14:0	18:3	20:0	20:1	22:0	24:0
	%	%	%	%	%	%	%
1. EVOO	M 0.5	M 0.1	M 0.9	M 0.7	M 0.5	M 0.3	M 0.5
2. FVOO	M 0.5	M 0.1	M 0.9	M 0.7	M 0.5	M 0.3	M 0.5
3. SFVOL	M 0.5	M 0.1	M 0.9	M 0.7	M 0.5	M 0.3	M 0.5
4. LVOL	M 0.5	M 0.1	M 0.9	M 0.7	M 0.5	M 0.3	M 0.5
5. ROO	M 0.5	M 0.1	M 0.9	M 0.7	M 0.5	M 0.3	M 0.5
6. OO	M 0.5	M 0.1	M 0.9	M 0.7	M 0.5	M 0.3	M 0.5
7. COPO	M 0.5	M 0.1	M 0.9	M 0.7	M 0.5	M 0.3	M 0.5
8. ROPO	M 0.5	M 0.1	M 0.9	M 0.7	M 0.5	M 0.3	M 0.5
9. OPO	M 0.5	M 0.1	M 0.9	M 0.7	M 0.5	M 0.3	M 0.5

M = Maximum

given to oils to eliminate the non-saponifiable part, thus showing up blends with non-olive oils.

DIETARY USES

On account of their organoleptic characteristics and its unusual acid composition, the different categories of olive oil are used in many ways for different food uses.

Each of the categories tends to have a specific application although it can be used for many purposes.

VIRGIN OILS, USED COLD

At room temperature, the taste of these oils makes them very suitable as dressings. In view of the wide range of organoleptic characteristics depending on the origin of the oil, it is possible to obtain different flavours or to select a specific aroma.

It can also be used to prepare sauces, in smaller proportions than with other oils, to achieve the desired flavour.

VIRGIN OILS, USED HOT

For the same reasons, the use of oil is particularly suitable for dressings prepared at temperatures close to the boiling point of water, such as the sauces used in the Mediterranean diet. In these preparations, particular care must be taken to retain in the sauce the typical taste of the aromatic constituents of the oil which are generally volatile, especially in steam.

Virgin oil is less widely used for frying but, even in this case, the food fried in olive oil takes on a special fragrance as the aromatic constituents are absorbed by the most porous parts of the food.

BLENDS OF REFINED AND VIRGIN OILS

Blends of different olive oils are used for the same purposes (both hot and cold) as the virgin oils which they resemble, though with a less pronounced taste, depending on the quantity used and the origin of the virgin oil added.

Blends of pomace and olive oils can be used in the same way as olive oils and are a cheaper alternative but they are most appropriate for frying, on account of their stability when heated and their mild aroma.

OLIVE OILS IN FRYING

Cooking at high temperature (around 180ºC) is a fairly complicated process due to the interactions between the oil and the air, causing oxidation, and between the oil and the food.

The stability of the fatty acids in the oil is a decisive factor: in theory, the best product for frying would be completely saturated fatty acids but this is not possible because of their nutritional qualities (Varela, G., 1988).

Fatty acids owe their stability to the absence of unsaturation centres, where oxidation phenomena tend to occur. Nutritionally useful and only slightly less stable are mono-unsaturated fatty acids, such as oleic acid which constitutes approximately 75-80% of the fatty acids of olive oil.

From the point of view of resistance to oxidation, therefore, this oil is the most suitable for frying.

The interaction with the food being cooked can be classified as follows:

- Absorption by the fried food
- Reactions of the volatile products with the food
- Reactions of the non-volatile products with the food

All these possibilities are minimised when a stable oil such as olive oil is used because chemical breakdown is reduced (as is the possibility of reactions occurring), and also because there are fewer breakdown products in the oil absorbed by the food.

OIL MILL WASTE WATER

Olives contain a sizeable fraction of an aqueous solution of various substances, known as vegetable water. When the olives are pressed, this is distributed between the pomace and the liquid effluent, which in certain extraction technologies is increased by adding water.

Until recently, the waste water was discharged into the environment or used for fertilisation, but environmental regulations now restrict such practices; waste water now has to be treated to reduce the amount of contaminating substances to admissible levels.

COMPOSITION OF VEGETABLE WATER

On average, vegetable water is composed of 83-96% water, 3.5-15% organic substances and 0.2-2% mineral salts. The organic substances are very complex and are listed in Table 13 (in dry state).

The above composition is highly simplified.

WASTE WATER TREATMENT

Although such technology is still developing, the main methods of waste water treatment are:

- Storage tanks which should lead to auto-purification;
- Anaerobic fermentation, with production of gas;

- Reverse osmosis and ultra-filtration with separation of certain products;
- Concentration and utilisation of concentrates;
- Drying together with the pomace before solvent extraction;
- Addition of reagents such as ozone to eliminate certain groups of substances that do not break down easily.

Some of these possibilities can be used in combination but none of the methods seem likely to provide a completely satisfactory solution to the problem.

TABLE 13
AVERAGE COMPOSITION OF VEGETABLE WATER (%)

Sugars	50
Nitrogen compounds	15
Organic acids and phenols	10
Pectin	10
Fats	7
Poly-alcohols	8

BY-PRODUCTS OF WASTE WATER TREATMENT

In view of the above, there do not seem to be any real by-products which would make it possible to recover, at least in part, the cost of purification. One potential solution could be in the animal feed sector in the production of concentrates, or perhaps it will be necessary to change the philosophy and gear waste water treatment towards the recovery of certain constituents with a greater added value.

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Chapter 8

TABLE OLIVE PROCESSING TECHNOLOGY

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TABLE OLIVE PROCESSING TECHNOLOGY

GEORGES BALATSOURAS

As stated in other sections of the Encyclopaedia, the olive grew spontaneously in the Middle East and Egypt and from there spread to the rest of the Mediterranean basin, being taken mainly by the Phoenicians and Greeks. It is not native to Central and Latin America nor to other countries or continents where the soil and climate are similar to those of the Mediterranean area. In these countries the olive tree was imported by Spanish or Italian emigrants and was either cultivated systematically or grown amongst other tree or annual crops.

STATISTICAL DATA ON THE PRODUCTION AND MARKETING OF TABLE OLIVES

TOTAL PRODUCTION OF TABLE OLIVES[49]

Total worldwide production of table olives over the six-year period from 1986-87 to 1991-92 is given in Tables 1 and 2.

It varied between 800,000 and 900,000 tonnes and increased especially as a result of the use of dual-purpose olives for processing as table olives.

TABLE OLIVE PRODUCTION IN EU COUNTRIES

Table olive production in EU countries for the same six-year period is given in Table 1. It fluctuated between 39% and 52% of the world total.

Spain, the EU country with the highest production, increased its average total to 230,000 by using dual-purpose varieties such as Hojiblanca, Lechín and Cacereña. The quantity of treated black olives showed the greatest increase and now reaches 60-70,000 tonnes annually.

Italy follows Spain with an average annual production of 83,000 tonnes of table olives. Quality has recently improved by promoting the cultivation of the good-quality variety Nocellara di Belice in Sicily (Trapani, Castelvetrano). Italy exports table olives but also imports them from Spain, Greece, Tunisia and Morocco.

Greece appears third in the table with an annual average production of 75,000 tonnes. Its table olives in all cases are from special table olive varieties, never from dual-purpose ones. The preparation of treated black olives is illegal in Greece.

Portugal produces 18,300 tonnes and France just 1,900 tonnes annually.

TABLE OLIVE PRODUCTION IN COUNTRIES OUTSIDE THE EU

Table olive production in countries outside the EU is given in Table 1.

Turkey produces large quantities of table olives, most of which come from dual-purpose varieties and are sold on the domestic market. Exports are negligible (10,000 tonnes annually).

The USA mainly produces treated black olives and Spanish-style green olives. Average annual production during the six-year period from 1986/87 to 1991/92 was 83,300 tonnes, all within California.

During the same period Morocco produced an average of 75,000 tonnes, including all the main trade preparations, most of which were exported.

Syria is also a table-olive producing country. Its average annual production was estimated at 61,300 tonnes during the same six-year period. It is mostly based on large-fruited varieties growing around Damascus and on the two dual-purpose varieties of Sourani and Tem-

Cultivar: Manzanilla (Dos Hermanas).

TABLE 1
TABLE OLIVE PRODUCTION WORLDWIDE OF ALL CATEGORIES (in thousand tonnes)
DURING THE SIX YEAR PERIOD FROM 1986-1987 TO 1991-1992

	Countries	1986/1987	1987/1988	1988/1989	1989/1990	1990/1991	1991/1992
1	ALGERIA	7.0	7.0	3.5	9.5	8.5	11.5
2	ARGENTINA	33.0	35.0	30.0	32.0	35.0	30.0
3	CYPRUS	3.0	3.5	3.0	9.0	5.0	7.0
4	CE (12)	376.5	388.5	362.0	494.0	370.0	463.0
5	ISRAEL	14.1	1.0	19.0	11.0	17.0	15.0
6	JORDAN	11.0	8.0	5.0	5.0	16.0	13.0
7	LEBANON	6.0	5.0	6.0	5.0	6.0	4.0
8	MOROCCO	70.0	70.0	70.0	80.0	80.0	90.0
9	SYRIA	81.0	50.0	72.0	35.0	80.0	50.0
10	TUNISIA	10.0	7.0	7.0	12.0	12.0	14.0
11	TURKEY	115.0	95.0	110.0	80.0	50.0	110.0
12	YUGOSLAVIA	-	0.5	0.5	0.5	0.5	0.5
13	LIBYA	2.0	2.5	2.0	2.5	3.0	3.5
14	EGYPT	21.0	15.0	18.0	21.0	10.5	9.0
15	AUSTRALIA	2.0	1.5	2.0	2.0	2.0	2.0
16	BRAZIL	1.5	1.0	1.0	1.0	1.0	1.0
17	CHILE	4.0	4.0	5.0	5.0	6.0	9.0
18	MEXICO	11.0	10.0	12.0	12.0	10.0	8.0
19	PERU	15.0	16.0	18.0	15.0	14.0	10.0
20	USA.	96.0	60.0	79.0	106.5	114.5	50.0
21	OTHER COUNTRIES	8.0	8.5	9.0	8.0	8.0	7.0
	TOTAL	887	789	834	946	949.0	907.5

prani that are grown in the northern areas of the country.

Argentina's table olive production averaged 32,500 tonnes during the same six-year period and was mostly based on olives of the Arauco variety. Both Spanish-style green olives and treated black olives are produced.

Other countries producing small amounts of table olives are Egypt, Israel, Peru and Tunisia.

INTERNATIONAL TRADE IN TABLE OLIVES

200,000 tonnes of table olives representing approximately 22% of total table olive production are sold internationally, with the remaining 78% being consumed on national markets.

Importer countries are given in Table 3 and exporter countries in Table 4.

Data concerning table olive production and trade in EU countries over the six-year period from 1986/87 to 1991/92 is given in Table 2

The country with the highest figures for exports is Spain followed at a distance by Greece and Morocco. These three countries exported annually 135,000, 47,000 and 44,900 tonnes respectively on average during the same six-year period. Argentina, Turkey and Portugal exported 18,700, 7,000 and 3,000 tonnes respectively during the same period whereas the quantities exported by Jordan, Israel and Tunisia were negligible.

Italy, France and the USA both export and import table olives.

TRADE PREPARATIONS

Taking the colour of the final product as the only criterion, table olives are classified in three colour groups – green, black and turning colour.

Annual production of each category over the six-year period from 1986-1987 to 1991-1992 is given in Table 5.

It fluctuated between 329,000 and 439,000 tonnes for green olives (41.5-46.5% of the total), between 291,000 and 352,000 tonnes for black olives (33-39% of the total) and between 160,000 and 212,000 tonnes for olives turning colour (20-22% of the total).

TABLE OLIVE CONSUMPTION[42]

The Near East countries of Lebanon, Syria and Turkey consume the largest quantities of table olives per capita (4.04, 4.03 and 3.45 Kg respectively).

Next come the Mediterranean countries of Greece with 2.5 Kg, Portugal with 1.91 Kg and Spain with 1.24 Kg per capita.

Among non-producing countries, Bulgaria is the leading consumer of table olives with 1.12 Kg per capita per year (see Table 6).

Cultivar: Arauco (Argentina).

TABLE 2
DATA ON PRODUCTION AND COMMERCIALIZATION OF TABLE OLIVES IN THE EEC COUNTRIES (in tonnes) DURING THE SIX YEAR PERIOD FROM 1986-1987 TO 1991-1992

	Country	1986/1987	1987/1988	1988/1989	1989/1990	1990/1991	1991/1992
A.	PRODUCTION						
1	Spain	224,000	231,500	180,000	280,000	236,800	229,800
2	France	1,500	2,500	2,300	2,100	1,000	2,000
3	Greece	80,000	60,000	85,000	70,000	70,000	85,000
4	Italy	50,000	75,000	79,500	122,100	44,500	130,000
5	Portugal	21,000	20,000	15,000	20,000	18,000	16,000
	Total	376,500	389,000	361,800	494,200	370,300	462,800
B.	IMPORTS						
1	Germany	9,500	9,500	10,000	13,500	14,000	14,500
2	Denmark	500	500	500	600	700	700
3	Spain	-	-	-	400	-	-
4	France	29,000	27,500	30,800	30,500	35,000	34,000
5	Greece	-	-	-	-	-	-
6	Ireland	-	-	-	-	200	200
7	Italy	49,000	39,000	47,500	48,200	75,000	4,000
8	Netherlands	500	2,000	2,500	2,500	2,700	-
9	Portugal	-	-	-	3,600	-	2,000
10	UK	2,000	1,500	2,200	2,300	3,100	3,500
11	Benelux	-	2,500	2,400	2,400	3,100	3,000
	Total	90,500	82,500	95,900	105,000	133,700	100,600
C.	EXPORTS						
1	Germany	-	-	-	600	500	50
2	Denmark	-	-	-	-	-	-
3	Spain	135,000	145,000	130,000	127,000	135,000	135,000
4	France	2,500	3,000	2,500	2,400	3,500	3,500
5	Greece	52,500	45,000	50,000	45,000	47,000	47,000
6	Ireland	-	-	-	-	100	-
7	Italy	2,000	1,500	1,000	1,000	2,000	2,500
8	Netherlands	500	-	200	200	300	-
9	Portugal	3,500	3,500	3,500	3,200	3,000	3,000
10	UK	-	-	-	100	100	100
11	Benelux	-	-	200	200	400	400
	Total	196,000	198,000	187,400	180,000	191,900	192,000

TABLE 3
IMPORTS OF TABLE OLIVES WORLDWIDE (in thousand tonnes)

	Country	1986/1987	1987/1988	1988/1989	1989/1990	1990/1991	1991/1992
1	Algeria	0.0	0.0	0.0	0.0	0.0	0.0
2	Argentina	0.0	0.0	0.0	0.0	0.0	0.0
3	Cyprus	1.0	1.0	1.0	0.0	0.0	0.0
4	EEC (12)	29.0	26.5	32.0	33.5	38.0	33.0
5	Israel	0.5	0.5	0.0	0.0	0.0	0.0
6	Jordan	0.5	1.0	0.0	1.5	0.0	0.0
7	Lebanon	1.0	1.0	1.0	1.0	1.0	1.0
8	Morocco	0.0	0.0	0.0	0.0	0.0	0.0
9	Syria	0.0	0.0	0.0	0.0	0.0	0.0
10	Tunisia	0.0	0.0	0.0	0.0	0.0	0.0
11	Turkey	0.0	0.0	0.0	0.0	0.0	0.0
12	Yugoslavia	1.0	1.0	1.0	1.0	1.0	0.5
13	Libya	7.0	6.5	6.5	7.0	5.0	5.0
14	Egypt	0.0	1.5	1.0	0.0	0.0	1.0
15	Australia	3.5	0.56	1.5	5.5	5.5	6.0
16	Brazil	18.0	20.0	23.0	22.0	23.5	24.0
17	Chile	0.0	0.0	0.0	0.0	0.5	0.5
18	Mexico	0.0	0.0	0.0	0.0	0.0	0.0
19	Peru	0.0	0.0	0.0	0.0	0.0	0.0
20	USA	80.0	88.0	80.0	68.5	64.0	86.5
21	Other olive-producing countries	1.0	0.5	0.5	1.5	1.0	1.5
22	Bulgaria	6.0	5.0	5.0	5.0	4.0	4.0
23	Canada	11.0	12.0	12.3	13.0	13.0	13.0
24	Romania	12.0	7.0	7.0	7.0	5.0	4.0
25	Switzerland	1.5	2.0	2.0	3.0	3.0	3.0
26	USSR	3.0	3.5	4.0	4.5	4.0	3.5
27	Venezuela	2.0	2.5	2.5	2.5	2.5	2.5
28	Other non-olive producing countries	18.5	18.0	18.0	18.5	18.5	19.0
	TOTAL	196.5	198.0	198.0	194.5	189.5	208.5

TABLE OLIVE VARIETIES WORLDWIDE

SPANISH VARIETIES[41]

Sevillana or Gordal (*Olea europaea regalis*, Clemente)

This is the most important table olive variety of Spain together with Manzanilla. It is grown in Andalusia, especially in the province of Seville.

The fruit is large (an average of 100-120 olives per Kg) with a flesh-to-stone ratio of 7.5:1. The shape is ellipsoidal with an indent at the stem end that makes it slightly heart-shaped. The epidermis is thin and speckled with white spots. The flesh is compact and the fruit colour is bright green at first, changing to purplish-black upon complete maturity. The oil content is 10% of the fruit weight and sugar content is 4-6% which facilitates fermentation, at the end of which the colour turns to golden yellow. The acidity of the brine, without any intervention, reaches 1% or more (grams of lactic acid per 100 ml of brine).

A special clone of this variety is grown successfully in Algeria (Relizane, Djidiouia) named 'Spanish Sevillana'. The only drawback of this variety is that the flesh is difficult to detach from the stone.

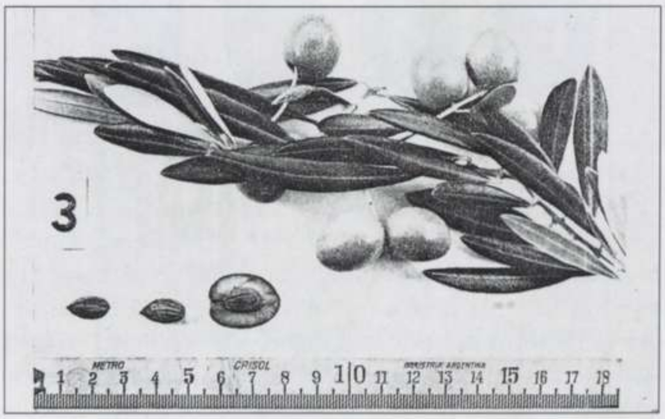
TABLE 4
EXPORTS OF TABLE OLIVES WORLDWIDE (in tonnes)
DURING THE SIX YEAR PERIOD FROM 1986-1987 TO 1991-1992

	Country	1986/1987	1987/1988	1988/1989	1989/1990	1990/1991	1991/1992
1	Algeria	500	500	-	-	500	1.500
2	Argentina	18.500	19.000	20.000	18.000	20.000	17.000
3	Cyprus	-	-	-	-	-	-
4	EEC (12)	135.000	139.000	199.000	118.000	111.000	122.000
5	Israel	500	-	3.000	3.000	3.000	2.000
6	Jordan	2.000	1.000	1.000	1.000	1.000	1.000
7	Lebanon	-	-	-	-	-	-
8	Morocco	44.000	33.000	41.000	43.500	53.000	55.000
9	Syria	-	-	-	-	-	-
10	Tunisia	500	500	500	2.000	500	1.000
11	Turkey	9.000	8.000	6.000	2.000	8.000	8.000
12	Yugoslavia	-	-	-	-	-	-
13	Libya	-	-	-	-	-	-
14	Egypt	-	-	-	-	-	-
15	Australia	-	-	-	-	-	-
16	Brazil	-	-	-	-	-	-
17	Chile	-	-	-	-	-	1.500
18	Mexico	-	-	-	-	-	-
19	Peru	-	-	-	-	-	-
20	USA	1.500	2.000	2.000	2.500	3.000	3.000
21	Other olive-producing countries	-	-	-	-	-	-
22	Bulgaria	-	-	-	-	-	-
23	Canada	-	-	-	-	-	-
24	Romania	-	-	-	-	-	-
25	Switzerland	-	-	-	-	-	-
26	USSR	-	-	-	-	-	-
27	Venezuela	-	-	-	-	-	-
28	Other non-olive producing countries	-	-	-	-	-	-
	TOTAL	211.500	203.000	192.500	190.00	202.500	212.000

Manzanilla (Olea europaea pomiformis)

This is the queen of all the table olive varieties and is grown not only in Spain but worldwide. It is a robust variety with a well-developed canopy. It sets single fruits of medium size that are symmetrical and apple-shaped, as indicated by the name (*manzanilla - small apple*). The skin is green with tiny whitish spots, becoming a purplish black upon maturity.

Manzanilla grows in areas with a mild climate and prefers alluvial soils such as those found in the Guadalquivir valley and the province of Seville. The fruit contains fewer sugars than the Sevillana and therefore ferments with greater difficulty. Total acidity in the brine reaches 0.6%-0.8%, rarely 1% without intervention, and this results in



Cultivar: Sevillana or Gordal (Spain).

TABLE 5
A) PRODUCTION OF TRADE PREPARATIONS OF TABLE OLIVE
DURING THE SIX YEAR PERIOD FROM 1986-1987 TO 1991-1992

	Commercial type	1986/1987	1987/1988	1988/1989	1989/1990	1990/1991	1991/1992
1	Green olives	378,5	329,0	345,5	439,5	419,5	390,5
2	Black olives	306,0	291,0	328,5	312,5	317,5	352,5
3	Olives turning colour and other types	202,5	169,0	160,0	194,0	212,0	164,0
	TOTAL	887,0	789,0	834,0	946,0	949,0	907,0

B) PRODUCTION OF TRADE PREPARATIONS OF TABLE OLIVE DURING THE SIX YEAR PERIOD
FROM 1986-1987 TO 1991-1992 IN PERCENTAGES OF TOTAL PRODUCTION

	Commercial type	1986/1987	1987/1988	1988/1989	1989/1990	1990/1991	1991/1992
1	Green olives	42,7 %	41,7 %	41,4 %	46,4 %	44,2 %	43,0 %
2	Black olives	34,5 %	36,9 %	39,4 %	33,0 %	33,4 %	38,9 %
3	Olives turning colour and other types	22,8 %	21,4 %	19,2 %	20,6 %	22,4 %	18,1 %
	TOTAL	100,0 %	100,0 %	100,0 %	100,0 %	100,0 %	100,0 %

a final pH value of 4.2 or more. The skin itself is thin, resistant to 'yeast spots' and 'fish-eye' deterioration but sensitive to blistering and peeling during the lye treatment. It is also prone to the deterioration called *zapatería* because of the deficient acidity of the fermentation process. The fruits must be stored for 24-28 hours immediately after harvesting and before the lye treatment.

Hojiblanca (*Olea europaea arolensis*)

This is a dual-purpose variety grown mainly in Andalusia, especially in the province of Cordoba. Until recently, the fruits of Hojiblanca were used exclusively for olive oil production. It is a late ripener that is moderately vigorous, giving a fruit with a regular shape and well proportioned stone. The epidermis is thin and the flesh has a good texture and is rich in phenolic substances. This variety is highly prized for the production of treated black olives. 60,000-70,000 tonnes of this trade preparation are now produced in Spain annually, mostly using Hojiblanca fruits.

TABLE 6
TABLE OLIVE CONSUMPTION PER CAPITA IN THE VARIOUS
OLIVE-PRODUCING COUNTRIES

	Country	Table olive consumption per capita (Kg)	Observations
1	Spain	1.24	Second quality table olives are usually consumed
2	Portugal	1.91	—
3	Greece	2.50	Mainly black olives in brine and Kalamata olives in vinegar
4	Bulgaria	1.12	The necessary quantities are imported
5	Turkey	3.45	Olives are served with breakfast
6	Syria	4.03	Olives are served with breakfast
7	Lebanon	4.04	Olives are served with breakfast

Cacereña

This is a dual-purpose variety which is considered a clone of the Manzanilla variety. Its fruit is mostly used for the production of treated black olives.

ITALIAN VARIETIES[14]

Italy is the second largest producer of olive oil but not of table olives. It currently uses the produce of approximately ten large-fruited varieties for processing as table olives although some of them do not have very suitable characteristics for this purpose. Recently, however, the Nocellara di Belice variety is being increasingly grown in Sicily and is a choice table olive variety.

Nocellara di Belice[70]

This is now considered the best Italian table olive variety (Venezia et al. 1986). Its fruit is mainly processed to make Castelvetrano-style table olives. Most of the orchards are irrigated and are only left dry in areas having an annual rainfall of about 550-560 mm.

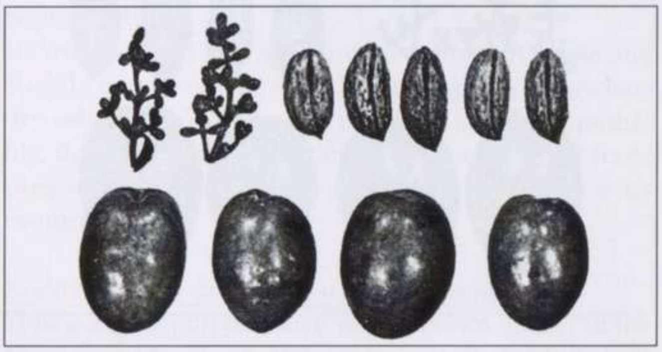
The fruit is of medium size, weighing 6-8 g, is round or oval-shaped and is similar to that of the Manzanilla and Konservolia varieties. The flesh-to-stone ratio is 6.5-8:1 and the fruit has all the quality characteristics to make it suitable for processing as table olives. Some trees of the Giarrafa cultivar are always grown in orchards of Nocellara di Belice for the purpose of cross-pollination.

Ascolana tenera
This is the most widespread table olive variety in Italy and is also grown in other countries such as Israel, Mexico, Argentina, California, etc. Ascolana tenera and Gordal are not two clones of the same variety as claimed by Baldini and Scaramuzzi (1957)[13]. The trees are vigorous and the fruits are of medium size weighing around 8.7 g, ellipsoidal and slightly asymmetrical.
For the production of Spanish-style green olives, the fruit is harvested when the skin is greenish-yellow. Afterwards the skin colour changes to a velvety red and then turns blackish.
The fruits contain 17-18% oil and are considered in California to be of inferior quality because of the relatively soft flesh and the sensitivity of the skin to lye treatment. Although it is the fourth variety in terms of numbers of trees grown in California, it is considered less productive than certain other cultivars also grown there such as Sevillana, Manzanilla, Mission, etc. Ascolana tenera and its various clones are grown in certain regions of Italy, including Sicily, together with Nocellara di Belice.

Cucco
This variety is exclusive to Italy and is grown in the Chieti and Pescara regions. The fruits are large, ellipsoidal and slightly asymmetrical. The trees are resistant to environmental adversities such as cold and cycloconium. The skin retains the green colour longer than most other varieties and turns winey-black upon complete maturity. The fruit contains 17% oil which is normally of good quality. If fermented, it gives Spanish-style green olives without any particular technological or organoleptic characteristics.

Sant Agostino
This is a large-fruited variety grown in Apulia and specifically in Andria, also being known as 'oliva di Andria' or 'oliva grossa andriesana'. The fruits grow in bunches of two or three per pedicel and are ellipsoidal in shape. Average fruit weight is 7.4 g with approximately 135 fruits weighing 1 Kg. Oil content is 14-15% and the fruit is mostly processed to give Spanish-style green olives.

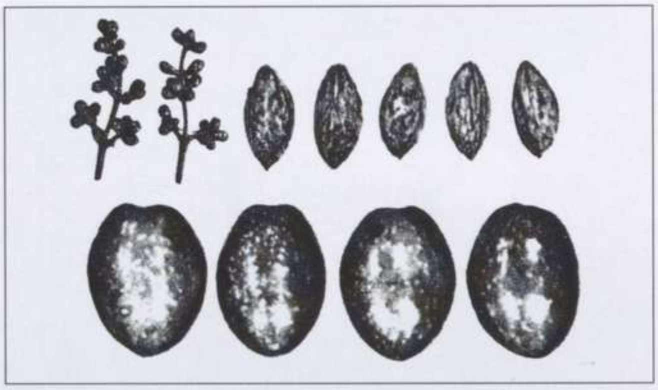
Typical containers for carrying the fruits of cv Nocellara di Belice.



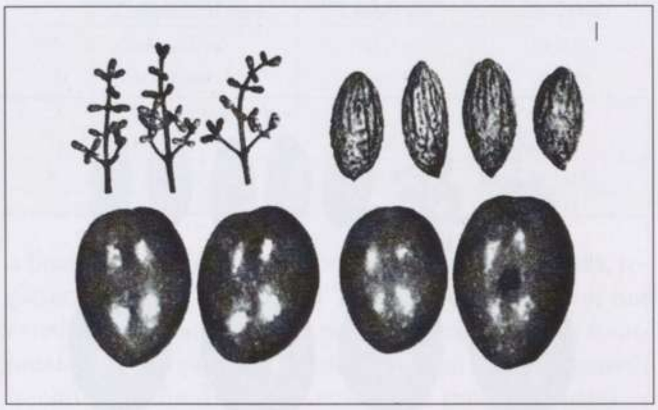
Ascolana Tenera.

Cucco.

Santa Caterina
This variety is grown in central Italy in the provinces of Lucca, Firenze and Grosseto. As a rule 120 olives weigh 1 Kg (average weight is 8.33 g per fruit). They are ellipsoidal in shape and asymmetrical. The skin is spotted and these spots can still be seen at complete maturity. The variety is resistant to cold but not very resistant



Sant'Agostino.



Santa Caterina.

Bella di Spagna o Cerignola.

to cycloconium and, while fairly productive, is not of any particular interest either for table olive processing or for olive oil production. Oil content is 17%. Most of these olives are sent for crushing.

Bella di Spagna or Cerignola

This is a large-fruited table olive variety grown sporadically in certain regions of central Italy. The tree is moderately vigorous with a dense canopy and hanging branches. Fruits weigh an average of 9 g with 110 fruits making up 1 Kg. They are ellipsoidal in shape, elongated and slightly asymmetrical. The fruit has the shape of an inverted cone. Skin colour turns deep black with white dots upon complete maturity. Apart from its large size, the Cerignola fruit has no other particular technological advantage. It is used for the production of Spanish-style green olives. Total production is limited and is generally sold on local markets.

GREEK VARIETIES

Konservolia

This is the best variety for the production of untreated black olives in brine. It is grown in central Greece in a belt extending from the Ionian Sea to the Volos region and beyond to the Sporades islands of the Aegean Sea. Certain areas producing the Konservolia variety in central Greece such as Agrinion, Amifssa, Atalanti, Aghios Constantinos, Stylida, Volos, etc. are internationally known for their top quality produce. The fruits are of medium to large size, weighing between 5 and 12 g depending on the tree load. They are round to oval with a flesh-to-stone ratio of 8-10:1. On average 180-200 fruits weigh 1 Kg. The skin is thin and elastic and is resistant to shrivelling. It can tolerate a salt content in the brine of 10% or more.

The Konservolia fruits ripen late, from mid-November to January-February and, in years of heavy production, up to early spring. Skin colour changes gradually from deep green to greenish-yellow, straw yellow, rose, reddish-purple, purple and finally jet black at complete maturity. There are white dots on the skin at all stages of fruit development.

Part of the crop is harvested from September 20 to mid-November while the olives are green for lactic acid fermentation for Spanish-style olives. The fruit has a good texture with fermentable substances accounting for 2-3% of the flesh and oil content is 20-25%.

Konservolia is a robust variety that grows from sea level up to an altitude of 600 m and is fairly productive provided it receives proper cultural care. The size of the tree canopy is small to medium in new plantations and uncontrollable in old ones which makes harvesting difficult. The Konservolia variety makes up 80-85% of table olive production in Greece.

Nychati of Kalamata (*Olea europaea var. ceraticarpa*)

This is the second most important olive variety in Greece. It is mostly grown in the southern region of the Peloponnese (Kalamata, Laconia) and also in central Greece (Aetoliko). The fruit is of medium size (from 3 to

Conservolea.

6 g on average) and has one curved side. It is cylindro-conical in shape. The skin turns dark black on maturity and the flesh retains a good texture. Oil content is estimated at 25.5% and fermentable substances at 3.10-3.5% of the wet olive paste. The tree is moderately vigorous, grows upright and has characteristically large leaves. It is sensitive to soil conditions but is productive and resistant to Dacus fly infestation. The flesh-to-stone ratio is good – about 8:1 and the fruit ripens in November or late December, depending on the heaviness of the crop. Total production of Kalamata olives is estimated at 8-10,000 tonnes and is expected to increase progressively as new plantations begin bearing. The fruit is used almost exclusively for the preparation of split Kalamata olives in brine acidified with vinegar. This trade preparation is well established in both national and international markets. The processed olives are of excellent texture, colour, taste and aroma. The added vinegar is not now considered a preservative so pierced Kalamata olives are now in great demand in high-income countries such as the USA, Canada and certain EU countries.

Chalkidiki

This is the third most important olive variety in Greece and is grown almost exclusively in the Chalkidiki peninsula (to the south east of Salonica). It is a large-fruited variety known as 'Gaidourolia' (donkey-olive). Almost 60% of the olive trees of the Chalkidiki peninsula belong to this variety. Fruit size is 6-10 g or even more when the tree load is light. Although large, the fruits are deficient in colouring and fermentable substances. Annual production of Chalkidiki olives is estimated at 8-10,000 tonnes, half of which is fermented as Spanish-style green olives, with the rest being crushed for oil. Olive oil yield is estimated at 19-20%.

The fruit of the Chalkidiki variety ferments with difficulty both when green and when ripe because of its deficiency in sugars and colour. *Zapateria* spoilage is likely to occur if the olives do not receive proper attention, and a ring of red colour may form around the pit of fermented green olives which is also considered a serious defect.

A similar ring is also formed in the fermented green fruit of Barouni, a Tunisian variety cultivated in California. On average, 120-140 fruits weigh 1 Kg and the flesh-to-stone ratio is 10:1. It has been claimed in the literature that the Chalkidiki variety resembles the Ascolana tenera because its fruit is cylindro-conical and terminates in a nipple.

Megaritici (*Olea europaea var. argentata*)

This is a dual-purpose variety grown mainly in the dry region of Attica.

Its fruit is small (2-5 g), cylindro-conical in shape and slightly curved on one side. It is used partly to produce dry-salted black olives and partly for oil. Quite probably, the dry-salted Megaritici olives were the first trade preparation of table olives among all olive-growing countries.

Kothreici (*Olea europaea var. minor rotunda*)

This is a dual-purpose olive variety grown mainly in the Focia area (Arachova, Delphi, Crisso). Its fruit is small (2-4 g) and is similar in shape to the fruit of the Konservolia variety. It is used for both oil production and table olives. Its colour, texture and eating qualities are excellent. This variety grows well at high altitudes (up to 800 m) and is considered by many experts to be a clone of the Konservolia variety.

Karydolea (*Olea europaea var. maxima*)

This is grown exclusively on the island of Euboea and is considered to be a clone of the Konservolia variety although its fruit is more rounded in shape.

Thrubolea (*Olea europaea media oblonga*)

This variety is unique in that its fruit automatically loses its bitterness during ripening and becomes sweet on the tree. The fruit is small (1.5-5) g, and is cylindro-conical in shape, terminating in a small nipple. Thrubolea is cultivated in Attica, in some islands of the Aegean sea and also in Crete. Its fruit is used to prepare Throuba-style black olives.

Egoumenitsa

This is grown in the Egoumenitsa area. Its fruit is small (3-4.5 g) and is used for the production of Spanish-style green olives or untreated olives in brine. It may be a clone of the Konservolia variety producing fruit of smaller size.

OTHER VARIETIES USED FOR TABLE OLIVE PROCESSING

Sigoise[8]

This is an important dual-purpose olive variety grown mostly in northern Africa, especially Algeria, under various soil and climatic conditions. The tree is fairly vigorous with a canopy from which it is fairly easy to harvest the fruits by hand. It is productive and fairly resistant to environmental adversities.

Average fruit weight is 4.5-5.5 g and the flesh-to-stone ratio is 5:1, which is only just suitable for table olive processing.

The skin is thin, elastic and resistant to low temperatures, concentrated lye, concentrated brine, etc. becoming shiny jet black when completely ripe. Part of the crop is harvested at the green stage and fermented as Spanish-style green olives, part is processed when ripe and the rest is sent to olive oil factories. The most important features of the Sigoise olive are its compact texture, its deep black colour at complete maturity, the average oil content (14-17%) and the high sugar content of the flesh (up to 4%).

Arauco[47]

This is the main table olive variety of Argentina and was transplanted from the Iberian peninsula to the Rioja province by the first Spanish emigrants. The tree is vigorous, 8-12 m high and is sensitive to cold and drought and to most diseases. It is self-sterile and has to be cross-pollinated to set fruits satisfactorily. The fruit is large, asymmetrical and cylindro-conical with a broad base, a pointed apex and a flesh-to-stone ratio of 7.3-8:1. It is used for the preparation of Spanish-style green olives, olives turning colour in brine, and treated and untreated black olives in brine. The untreated black olives from the Aimogasta and Mazan regions of the Rioja province are of excellent quality and are well known in international markets.

The Arauco olive contains 17-18% oil and is also used to produce good quality olive oil which is well known for its greenish-yellow colour and fruit taste.

Massabi[9]

This is a large-fruited variety grown in Syria, mostly around Damascus. The fruits are elongated and end in a nipple. They are rich in sugar and are mostly fermented as Spanish-style green olives.

OTHER SYRIAN VARIETIES

These include the large-fruited Jlot, Dan and Tefahi varieties and the two dual-purpose, medium-sized Sourani and Temprani varieties.

The latter are grown widely in northern Syria (Aleppo, Salkin, Idlem, etc.) and their fruits are used both for crushing for oil and for processing as black olives. The Jlot variety resembles the Greek 'Nychati Kalamon' variety.

TURKISH DUAL-PURPOSE VARIETIES[26]

The most important of these are the Memeli, Domat and Izmir Sofralik varieties.

MOROCCAN DUAL-PURPOSE VARIETIES

The Picholine and Zitoun varieties are the most important for table olive production.

TUNISIAN DUAL-PURPOSE VARIETIES

These include the Chemlali and Chitoui varieties.

THE OLIVE FRUIT AS RAW MATERIAL FOR THE TABLE OLIVE INDUSTRY

STRUCTURE AND CONSTITUENT PARTS[4]

The olive fruit is a drupe similar to others such as the peach, apricot, cherry, plum, etc. It comprises:

- the epicarp or skin
- the mesocarp or flesh[26]
- the endocarp or stone, consisting of the woody shell that surrounds one and occasionally two seeds (kernels).

While the olive fruit does not differ morphologically from other drupes, its chemical composition and organoleptic properties are very different, especially the following:

- The relatively small concentration of sugars, i.e. 2.5-6% of the wet olive paste (resulting from the homogenisation of the epicarp and mesocarp).
- The increased quantities of fatty substances amounting to 17-30% of the wet olive paste and occurring in the form of distinct droplets in addition to the complex lipids (lipoproteins, phospholipids, glucolipids, etc.) that serve as building units of the cells and by extension as building units of the tissues.
- A bitter substance known as oleuropein that is peculiar to the olive fruit and distinguishes it not only from all other drupes but also from all other fruits of the plant kingdom.

Owing to these peculiarities, the olive fruit is the only drupe which is not sweet but decidedly bitter, even when ripe or overripe. For this reason, it is not eaten directly from the tree but only after a certain type of processing. Its bitter principle has to be removed, at least partially, before the fruit can be consumed.

The epicarp and mesocarp of the olive fruit, like all foods of plant origin, consist of parenchymatous cells. These cells are large, isodiametric (with a diameter of 50-300 mm and up to 1 mm) and are surrounded by a rigid cell wall. At the centre is a large vacuole full of sap in which are dissolved sugars, acids, tannins, water-soluble colouring substances, inorganic substances, etc. It also contains droplets of oil. There is cytoplasm between the vacuole and the cell wall surrounded by the cytoplasmic membrane which is selectively permeable. The polar substance of the cell sap exerts osmotic pressure on the walls (up to 9 atm.) which is counteracted by the inward pressure of the cellulosic cell wall. Therefore each cell and, by extension, the whole fruit has a definite shape. In a parallel manner, the osmotic pressure of the cell sap and the counter-pressure of the cell wall give the olive fruit its turgidity.

The parenchymatic cells of the mesocarp have nutritional and biological value for human consumption whereas the epicarp or skin is impregnated with the waterproof substance coutin and is indigestible. The endocarp or stone is also of no value and is rejected during mastication.

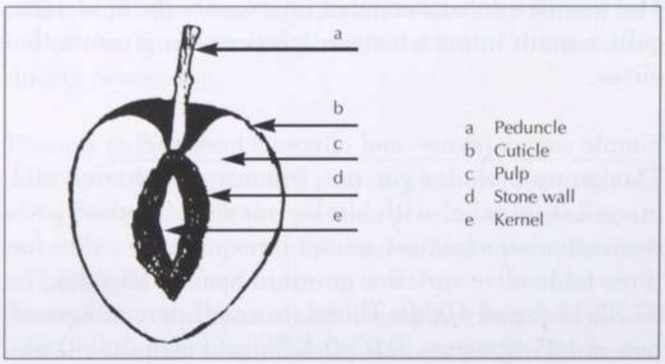
FLESH CONSTITUENTS

The main constituents of the flesh are:

- Water
- Fatty substances
- Simple sugars, including mannitol
- Other polysaccharides (celluloses, semicelluloses, gums, pentosans, etc.)
- Proteins
- Pectins
- Organic acids
- Tannins-phenols
- Oleuropein
- Vitamins (water soluble and liposoluble)
- Colouring substances
- Inorganic substances, etc.

Water or moisture content

Moisture is the main constituent of the table olive and reaches 65-72% of the weight of the fresh olive fruit depending on its firmness. It is 55-62% in table olives, depending on the process used and drops to 28-32% in olives in dry salt. It has no nutritive value so the lower the moisture content of processed olives, the higher their calory value.



Transversal section of the olive fruit with its constituent parts.

The moisture content is responsible for the regular shape of raw olives due to the fact that the cytoplasmic membranes are alive, selectively permeable and as such prevent excessive dehydration and shrivelling.

During processing, however, the selective permeability is lost by the exposure of the fruit to alkali, salt, anaerobic conditions, etc. so that the moisture retained by the flesh is in the form of a thin film around the colloidal particles. For the most part, these particles are proteins and so the lower the degree of denaturation the higher the moisture retained by the flesh and, by extension, the better the shape and appearance of the processed fruit. Undue denaturation of the colloidal protein (by early frost in the orchard, by concentrated lye or brine, etc.) results in an olive fruit that is irreversibly shrivelled and therefore unsuitable for processing as a table product. Shrivelling in dry salted olives is not objectionable and is considered to be a quality characteristic.

Under normal processing conditions olives lose moisture and other constituents and absorb salt from the brine. But the moisture retained is sufficient for them to be smooth externally in spite of a slight loss of weight which processors name 'waste'.

Fatty substances

These are not liable to waste during table olive processing because they are not water-soluble and as such are not transferred to the brine. There are two types of fatty acid – triglycerides in the form of distinct droplets and complex lipids that are the building units of the cell tissues. A small loss of about 10% has been observed in the fatty substances of fruit during lye treatment but generally the oil content of olives at the end of processing either remains unchanged or increases slightly because of the loss of water-soluble substances.

The wax-like substances that impregnate the epidermis cells remain intact whatever treatment is given to the olives.

Simple sugars (mono- and oligosaccharides)[65]

This group includes glucose, fructose, saccharose and mannitol (alcohol with six hydroxyls). Glucose predominates over fructose as can be seen in the ratios for three table olive varieties grown in Spain – 94.28:5.75, 87.85;12.5 and 100:0. There are small percentages of non-reducing sugars (0.03-0.42%) and mannitol (0.55-0.63%) in the wet flesh weight. The relatively high mannitol content plus the oleuropein are pecularities of the olive fruit.The sum of fermentable substances varies between 2.5% and 6.5% of the wet olive flesh depending on the variety, cultural practices, prevailing environmental conditions, etc. It has been proved in industrial practice that the higher the content of fermentable substances, the easier the fermentation of the fruit and its preservation during storage and marketing.

Fermentable substances are of no importance for treated black and dry-salted olives but are of specific interest for Spanish-style green olives, bruised green olives, untreated black olives in brine, etc. In general, the residue of fermentable stuff participates actively in the development of the organoleptic qualities of the end product[60].

According to the trade preparation, the effect on the fermentable substances during processing is:

- fermentation by the lactic acid bacteria or the yeasts
- oxidation by fungi, oxidative bacteria and yeasts
- they remain totally or partially intact

In Spanish-style green olives, almost 50% of the fermentable constituents are lost during lye treatment and subsequent washing. Those that remain are practically equally distributed between the flesh and the covering brine. Considering that the stone is inactive in this process and represents less than 20% of the total fruit weight and that the brine in each recipient amounts to 60-70% of the fruit weight it covers, only a quarter of the fermentable stuff present originally in the flesh is transferred into the brine when equilibrium is reached.

Under normal conditions the sugars in the brine are transformed into lactic acid through the agency of lactic acid bacteria.

Fermentation is of two types, homolactic and heterolactic. In the first, practically all the sugars are converted into lactic acid by the homofermentative lactic acid bacteria whereas, in the second type, the sugars are split into lactic acid, carbon dioxide and either acetic acid or ethyl alcohol depending on the redox potential of the fermenting olives. The sequence of reactions can be summarised as follows:

$$C_6H_{12}O_6 \xrightarrow{\text{homofermentative lactic acid bacteria}} 2CH_3CHOHCOOH$$

$$C_6H_{12}O_6 \xrightarrow{\text{homofermentative lactic acid bacteria}} CH_3CHOHCOOH+CO_2+CH_3COOH \text{ o } CH_3CH_2OH$$

Fermentable material equal to 4% of the flesh weight in the raw olives is sufficient to give an acidity of 0.8-1% (0.8 g of lactic acid per 100 ml of brine) in the brine of fermented Spanish-style green olives. Such acidity in the brine securing a pH value of 3.8-4.1, together with salt (8% or less) and anaerobiosis, preserve the olives for any length of time. Untreated black olives in brine do not have their bitterness removed by lye treatment and are not washed with water. The acidity of the brine by the end of processing has to be low (0.5-0.6) in order to ensure acceptable colour plus good eating qualities. Consequently, sugar content of 2-2.5% in the flesh of raw olives is sufficient for adequate processing.

Other polysaccharides

This group includes cellulose, hemicellulose, pentosans and by extension lignin, although the latter is a polymer of aromatic alcohols and aldehydes. Green olives of the Konservolia variety were found to contain 3.026% crude fibres when raw and 2.055% by the end of processing. The reduction of cellulosic material by approximately 32% during processing softens the flesh of the final product. In untreated black olives in brine of the Konservolia variety, the two figures before and after processing were 1.835% and 1.905% respectively. The small increase in crude fibres was due to a loss of water-soluble constituents from the flesh of the olive fruit.

Data in the Spanish bibliography regarding the behaviour of crude fibres in olives during processing corroborate the above findings. Obviously, the molecules of cellulose and lignin remain intact during processing and the loss of crude fibres is limited to semi-celluloses, pentosans, gums, etc. amounting together to 32% of the total weight of fibres. It is recorded in the Spanish literature that endogenous celluloses occur in the mesocarp of olives and partially degrade the macromolecule of cellulose leading to gradual ripening of the olive fruit and to slight softening of the tissue.

Proteins[60]

Some of the proteins in the olive mesocarp are water-soluble and the rest are insoluble. They occur in small percentages, up to 1.5% of the wet olive paste. They are of excellent quality because aminoacids, essential for the human organism and for the fastidious lactic acid bacteria, participate in building their molecule. The water-soluble portion of proteins is partly diffused in the brine together with other water-soluble constituents and they transform it into a nutritive substrate for the growth of desirable lactic acid bacteria but also of undesirable microbes. A loss of 20% protein in green olives of the Konservolia variety and 23% in untreated black olives of the same variety has been recorded during processing.

Pectins[60]

These are the main constituents of the intercellular cementing material, the so-called middle lamella, as in all plant tissues. They are of excellent quality and their eventual hydrolysis by physico-chemical means (alkali, increased temperature) or by hexogenous enzymes (of the micro-organisms grown in the brine) or endogenously in the flesh as it ripens or becomes over-ripe, leads to the complete softening of the tissues that eventually makes the product useless.The pectin content of the olive mesocarp is estimated at 1.86-2.32% (average 2.10%) while the pectin content of the epicarp is slightly lower. The pectinolytic enzymes that are responsible for the degradation of olive pectins are the polygalacturonases and pectinesterases but not the pectinolyases.

Organic acids[65]

The presence of three organic acids has been confirmed in the flesh of olive fruit, namely, oxalic, malic and citric, in quantities varying from 0.10% to 0.20% (total for the three) depending on the olive variety and the stage of development of the olive fruit. The paste (resulting from the homogenisation of the epicarp and the mesocarp) is slightly acid and has a pH of around 5.2-5.5.

The organic acids of the olive flesh play no part in the processing when it is based on the utilisation of sodium hydroxide (Spanish-style green olives, untreated black olives, etc.). On the other hand, for olives placed directly in brine (bruised or split green or black olives, untreated black olives in brine, etc.), from the start the organic acids create an acidic environment (about 5.5 pH) and thus prevent any deviation from the normal fermentation process and any alteration of the product during processing.

Phenols (tannins)

All olive tree tissues are rich in phenols, particularly olive flesh in which the phenols give a bitter and acrid taste. The most important phenol is oleuropein, the bitter principle of olive fruit.

According to the Spanish bibliography, raw green olives contain 7% phenols in the dry state and 1.96-2% in the wet state. Untreated black olives when fresh contain half this quantity, i.e. 0.98%. Lye treatment and washing drastically reduce the phenol content of green olives (1/3 of the initial quantity) and olives thus lose their pungent and bitter taste and become acceptable for consumption.

Phenols hinder the growth and activity of the lactic acid bacteria in the olive brine, while they may be the only carbon source for certain members of the mixed microflora.

The phenol content of olive flesh varies from one variety to another. In general, olive fruits rich in phenols are most suitable for processing as treated black olives because polyphenols in an alkaline environment are oxidised, giving the artificial black colour. Varieties rich in phenols are Hojiblanca and, to a lesser extent, Manzanilla. In addition, phenols (tannins) react with iron and intensify the black colour through the formation of iron tannate.

Oleuropein

Oleuropein is the phenolic substance of bitter taste that occurs exclusively in olive fruit and the other tissues of olive trees and in no other fruit of the plant kingdom. It is water-soluble and as such is extracted with water or brine and is degraded by lye. Since, together with the oleuropein, other water-soluble substances such as proteins, salts, fermentable substances, etc. are also extracted, and because these are valuable for the normal process of fermentation and also for nutritional reasons, much research work has been carried out since 1908 to find out how to remove the oleuropein from the flesh with the least possible loss of the other valuable water-soluble constituents.

According to the first study on oleuropein by Bourquelot and Ventilesco in 1908[15], oleuropein has a complex molecule with glycositic and esteric bonds, with reducing capabilities and with glucose as one of its building units. Its molecule is considered to be either a double ester of glucose with two aromatic acids (protocatehic and oleuropeic)[68] or a more complex structure having as building units dioxy-phenylethyl-alcohol, glucose and an acid named polyfunctional. The second version is more widely accepted without excluding the possibility that the bitterness of olives is due to two or more phenolic substances.

Oleuropein is removed partially or completely, depending on the trade preparation in question, by one of the following techniques:

- Packing the olive fruit with dry salt in alternating layers in baskets or wooden containers. The salt extracts the fruit juice that contains most of the oleuropein.
- Crushing or splitting the olives (green or black) then immersing in plain water that is changed once a day for a period of one week. Under such conditions, most of the oleuropein is extracted from the flesh, together with other water-soluble substances.
- Immersion of the olive fruits in a 1.6-2.5% NaOH solution in which they are left until 1/2 to 2/3 of the flesh is impregnated with the alkali solution. By this process the alkali hydrolyses the ester bonds and removes the bitterness. In contrast, hydrolysis of glycositic bonds by acids does not remove the bitterness of the olive fruit.

Vitamins[55]

The following vitamins occur in the olive fruit:

- Carotenes: 0.15 - 0.23 mg per 100 g of flesh
- Vitamin C: 12.9 - 19.1 mg per 100 g of flesh
- Thiamin: 0.54 - 11.0 mg per 100 g of flesh
- Vitamin E (tocopherol): 238.1-352 mg per 100 g of flesh

Of the above vitamins, those that are soluble in fat (carotenes and vitamin E) practically remain in the flesh until the end of processing, whereas the water-soluble ones (vitamin C and thiamin) are lost to a varying extent depending on the method of processing and the trade preparation being produced.

Colouring substances

Olive flesh contains fat-soluble colouring substances such as chlorophylls a and b as well as various carotenoids and water-soluble colouring substances such as anthocyanins.

The former are not extracted into the sodium hydroxide solution nor into the washing water nor into the covering brine during processing, packaging and marketing. The only loss takes place occasionally and is due to hydrolysis of the esteric bond connecting the phytol residue to the tetrapyrrole skeleton through the agency of the enzyme chlorophyllase or through the action of the sodium hydroxide solution during the removal of bitterness[48]. The phytol-free molecule of the chlorophylls becomes water-soluble and is transferred into the lye and the washing water causing the loss of approximately 20-25% of the total amount of chlorophylls[56].

Additionally, lactic acid in normal fermentation of green olives detaches the magnesium from the centre of the tetrapyrrole ring converting chlorophylls into pheophytins and pheophorbids. This conversion results in the fading of the green colour which may affect the quality of the final product.

Carotenoids are more resistant to the various treatments to which green olives are submitted and exhibit sensitivity only when their molecules are liable to oxidation[49].

The water-soluble colouring substances of olive fruit flesh are exclusively anthocyanins amongst which cyanidin, called oleocyanidin, predominates, accompanied by small quantities of pelargonidin and delphinidin. Synthesis of anthocyanins (anthocyanidins combined with sugar residues) starts as soon as the olives begin to ripen. In general, the anthocyanin colour is the main quality characteristic of untreated black olives in brine, split Kalamata olives, genuine Greek-style black olives, etc.

Their synthesis in the olive fruit flesh is mostly determined by the variety but also by the stage of ripeness, the intensity of sunshine in the region and the exposure of the olives to direct solar radiation.

Being water-soluble, the anthocyanins are practically equally distributed between the olive fruit and the covering brine at equilibrium. With this process, the colour fades and, if there are not sufficient anthocyanins in the fruit, the resulting light colour will lower the value of the product. Anthocyanins are sensitive indicators of pH and change colour in accordance with the pH values formed in the flesh and in the covering brine. At a low pH value (3.8-4.5), they develop a purple colour that changes progressively to violet, black-violet and finally to jet black when the pH reaches the neutral point.

Inorganic constituents[46]

The flesh of the olive fruit is rich in inorganic constituents. Potassium predominates, followed by calcium, magnesium, chlorine, phosphorus, etc.

A large proportion of them is lost during the various stages of processing into the lye, washing water, brine, etc.

Only the sodium content increases due to the addition of salt to all trade preparations of table olives. Nevertheless, the quantity of inorganic constituents remaining at the end of processing is sufficient for table olives to be considered a good source of minerals for the human organism and useful for the lactic acid bacteria developing in the brine. Of special interest is the magnesium, as well as the trace elements in the flesh such as iron, zinc and manganese.

SPANISH-STYLE GREEN OLIVES

There are two determining factors for classifying the various trade preparations of table olives, namely colour (green, black and turning colour) and the method of preservation (by the lactic or acetic acids in the brine, salt or anaerobiosis).

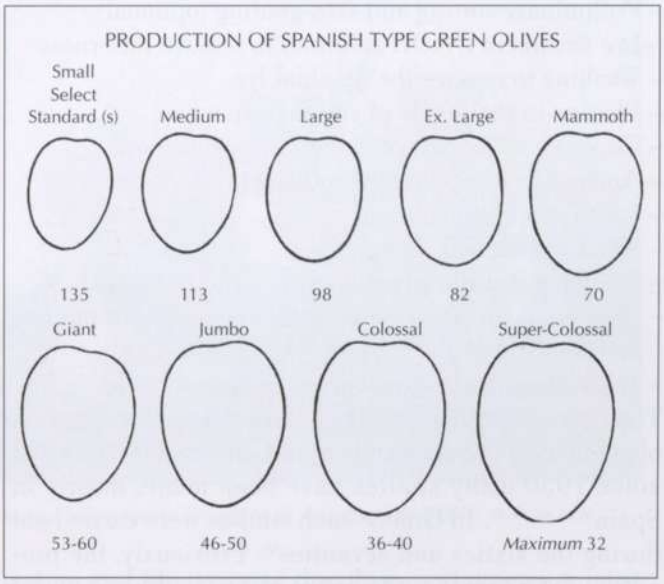
Preservation is safeguarded by a combination of these three factors, i.e. the acids that are related in each case to a certain pH value of the olives and the brine, the salt added in varying quantities and partial or complete anaerobiosis. But in each trade preparation only one of the three factors is really responsible for preservation (for example, lactic acid for Spanish-style green olives, solid salt in olives in dry salt and complete anaerobiosis combined with thermal treatment for treated black olives in cans, etc.).

So the combination of the three colours with the three methods of preservation means that in theory 9 types of table olive can be prepared although in fact there are many variations within a single type. The predominant trade preparations are Spanish-style green olives, untreated black olives in brine and olives darkened by oxidation. The remaining types such as split black olives, green olives in brine, black olives in dry salt, etc. are produced in relatively small quantities and are mainly destined for local markets. Altogether, they amount to approximately 20% of worldwide table olive production.

BACKGROUND

Spanish-style green olives are a traditional product of Spain and there are references to this method of production dating from the beginning of this century. Possibly green olives have for centuries been bruised or split and immersed in water to remove their bitterness or immersed in a lye of firewood ashes. The use of sodium hydroxide solution is a more recent technique generally applied in combination with fermentation which, until recently, was carried out in the open air in 500 Kg barrels. This technique was transplanted to Latin America by Spanish emigrants who used wooden vats holding 5-10 tonnes of olives.

In California olive cultivation began in 1860[64]. The table olive industry first attracted interest at the beginning of this century and resulted in the production of treated black olives. But serious outbreaks of botulism in the early twenties caused by inadequate sterilisation of cans caused widespread mistrust of black olives. The Spanish style of preparation that was introduced from Spain in 1927 was thought to be the only alternative and served as an outlet for the product. Fermentation took place outdoors in wooden barrels holding as little as 50 Kg of olives and this trade preparation then predominated in California up to around 1950. Public confidence in black olives in cans was gradually restored and this type regained its former position in the market, taking preference over others, and this is the situation today throughout the USA. Good quality olives are processed as olives darkened by oxidation (treated black olives) for packing in cans and the only olives that are processed green are those of small size or poor quality.



Size grades for olives. The numbers indicate the average number of olives per pound.

In Greece green olives were first fermented in 1952 but total production remained at 3,000 tonnes for several years[60]. It then started to rise and in recent years has reached a volume of 10,000 to 15,000 tonnes. But Spanish-style olives in Greece are comparatively less important than black olives.

Spanish-style olives are produced in appreciable quantities in the countries of northern Africa (Morocco, Algeria, Tunisia) and recently in Italy, France, Portugal, Turkey, etc. where the basic Spanish technique has been adopted with occasional slight modifications[5].

PROCESSING

The procedure followed for fermenting green olives is summarised below:

- Harvesting
- Transport to the factory

- Preliminary sorting and size-grading (optional)
- Lye treatment (NaOH solution) to remove bitterness
- Washing to remove the residual lye
- Placing in recipients of various capacities
- Covering with brine of varying concentration
- Anaerobiosis inside the recipients
- Lactic acid fermentation
- Final sorting and size-grading
- Pitting and stuffing (optional)
- Return to the recipients and covering with mature brine
- Repacking in glass containers or cans for sale

The first scientific research on lactic acid fermentation of green olives was carried out in California in 1943 and since 1950 many studies have been made, mostly in Spain[36,61,62,63,64]. In Greece such studies were carried out during the sixties and seventies[25]. Previously, the processing of Spanish-style green olives had been based upon experience and skill. Today it is performed under strict technological and scientific control.

The details of each stage of the process are given below.

Harvesting

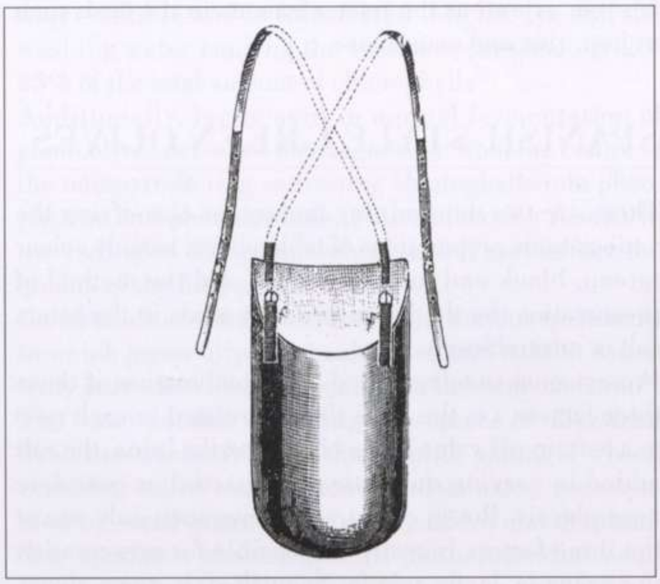
Harvesting should begin when the stone has developed fully and the mesocarp has practically reached its full size, before the colour changes from a yellowish-green to yellow with red spots.

The actual time of harvest varies from one region to another, being the first week of September in Relizane in Algeria, mid-September in Andalusia in Spain, the end of September in Greece, early October in California, and so on.

The fruits should preferably be picked by hand. Beating the trees is not advisable and in certain countries is not permitted because damaged green olives may disintegrate when immersed in the lye. Obviously harvesting is easiest when the tree canopy is of small to medium size but this is only the case in certain plantations in Spain or Italy.

The pickers hold the fruit-bearing branch with one hand and with the other 'milk off' the olive fruits either letting them fall onto plastic nets spread under the tree canopy or into bags hung around their necks.

In Israel vibrators are used to detach the olives. They fall first into the umbrella of the shaker and from there are directed into a sodium hydroxide solution. This solution is brought to the orchard in barrels and its concentration is calculated taking into account the distance between the processing plant and the olive orchard so that olives are impregnated with soda to the depth required by the time they reach the factory. While the use of shakers reduces the cost of harvesting, the fruits get scratched and bruised during shaking and such damage leaves black marks on the skin that remain practically unchanged during fermentation and reduce the value of the final product. In Andalusia (Spain), satisfactory results were not achieved as regards the impregnation of the flesh with soda up to the desired depth and trials with water instead of lye were also unsuccessful. The result is that all olives for table olive processing in Spain are now picked by hand.



Sack that pickers hang round their necks for damaged olives or olives collected from the ground.

Transport

The harvested olive fruit is placed in wooden or plastic crates and loaded onto trucks. In certain regions (Andalusia) the olives are loaded directly into tipper trucks lined with straw matting. Crates, if used, have holes in their sides to allow air to circulate through the fruit load. Olives are still living during transport to the factory and until immersed in the lye and therefore they respire at the expense of the sugars contained in the flesh according to the following reaction:

$$C_6H_{12}O_6 \xrightarrow[CO_2]{\text{respiration}} 6CO_2 + 6H_2O + 685\ \text{Kcal}$$

During respiration, heat is released which raises the temperature of the olive fruit load and leads to loss of moisture and deterioration. Also the breakdown of the sugars results in loss of weight (waste). To reduce these drawbacks as far as possible, the nearer the processing plants to the orchards the better and the daily input of fresh olive fruits has to parallel the plant's capacity to process them so that the olives are not kept waiting.

Preliminary sorting and size-grading

Sorting and size-grading before lye treatment are optional but are preferable if alkali penetration is to be uniform. They are also an advantage from the point of view of classification of the eventual marketable products.

However, preliminary sorting and size grading mean that valuable time is lost, especially in the high season, and the constant flow of olives from the orchard to the fermentation tanks is interrupted. Another disadvantage is that the plant is likely to find it difficult to fill large containers with the two extreme sizes (very small and very large). Qualitative sorting and size-grading are necessary anyway at the end of fermentation and before retail packaging. The weight of olives may vary during fermentation and some of them may become off-coloured, misshapen and blemished. In any event, carrying out sorting and size-grading twice increases the cost of processing and is limited only to processing plants of small capacity. Large plants process olives straight from the orchards, often together with leaves and twigs.

It is customary, however, at least in Andalusia, to pass the olive fruit through a size-grader with an air current to remove olives of very small size and most of the leaves and twigs.

In some areas the fruits are left to rest in a well-aired place for 24-48 hours immediately after harvest and before lye treatment, especially in the case of sensitive varieties such as Manzanilla in Andalusia and Sevillana in Relizane and Djidiouia (Algeria). Such a rest period reduces the firmness of the fruit so that sloughing and blistering of the skin are less likely to occur during lye treatment.

Total fruit loss without a rest period has been estimated at 7% but anomalies caused by introducing the rest period into the processing routine have been estimated to cost more than the value of the fruit lost. This practice is therefore only applied in small-scale processing plants.

Lye treatment to remove bitterness

Treating green olives with a sodium hydroxide solution to remove their bitterness is a prerequisite for the subsequent lactic acid fermentation. In Andalusia, which is considered the «metropolis» for the production of Spanish-style green olives, this process was considered to be the key to proper fermentation[41].

The dissolution of NaOH in water causes an exothermic reaction and the resulting hot solution would result in peeling and blistering of the olives so immersion must take place at a maximum temperature of 60-70ºC (15.5-21ºF).

Manual harvesting of drupes of cv. Nocellara de Belice.

The ideal concentration of the soda solution varies according to the variety of the fruit, its stage of ripeness, the temperature inside the processing plant, local customs, etc. but it rarely lies outside 1.6-2.4%.

During the process to remove the bitterness of the olives, which lasts 6-15 hours, the fruits have to be completely immersed in the alkaline solution otherwise those on the surface are oxidised (phenol oxidation in an alkaline environment) and turn a black colour which cannot subsequently be eliminated.

The lye treatment is brought to an end when the majority of the flesh has been penetrated by the alkali solution, leaving a ring around the stone unaffected by the lye. The lower the phenol content of the flesh the bigger this ring. Under no circumstances should the soda solution be allowed to penetrate all the flesh right up to the stone.

The olives are then washed in several changes of water but not too thoroughly to prevent the water-soluble and useful constituents of the flesh from being washed out and to reduce the amount of contaminants produced.

At the end of the de-bittering process, the olives have an oily green colour, an aroma of fresh hay and increased relative density which means that they sink in the washing water so no covers are necessary for the washing tanks.

It is important that some residual lye is left in the flesh because this, together with the lactic acid formed during fermentation, ensures the buffer capacity of the brine. It is actually a mixture of lactic acid and sodium lactate ($CH_3\ CHOH\ COOH + CH_3CHOHCOONa$) that facilitates normal lactic acid fermentation while

Olives awaiting lye treatment (Photograph by courtesy of F. Corchero).

also improving the organoleptic qualities of the final product.

In general, the higher the concentration of sodium hydroxide in the lye, the more uniform its penetration of the flesh, provided that the specific variety of olive can tolerate the concentration without any adverse effects to its skin and flesh.

The alkali solution does not selectively break down the oleuropein molecule but does the same also to other valuable constituents such as sugars, proteins, vitamins, etc. It also extracts minerals from the flesh. Consequently, the only source of fermentable constituents, other nutrients and also of small quantities of oleuropein is the intact ring that surrounds the stone. These nutrients support the growth of lactic acid bacteria and impart to the end product a slight bitterness which is part of the table olive's appeal for consumers.

- Lye treatment in different countries

In Andalusia the bitterness of Manzanilla olives is removed by means of a sodium hydroxide solution at 3-3.7 Bé within a period lasting 4-6 hours. With Gordal olives the process lasts 8-10 hours with a lye at 2-2.8 Bé.

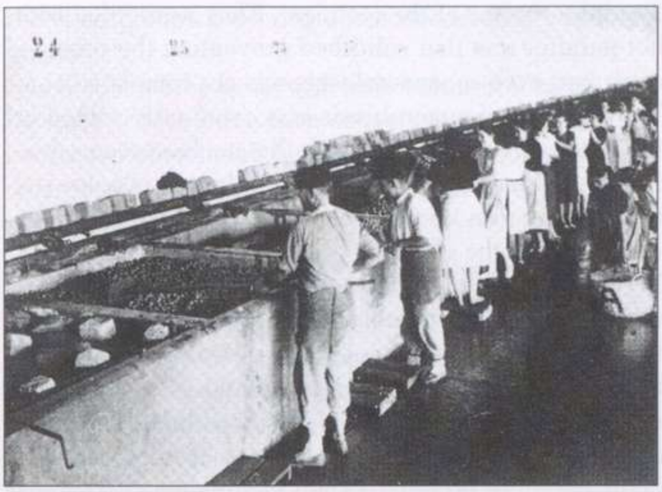
Table olive processing plants in Andalusia used to have a battery of reinforced concrete tanks for the lye treatment, each holding 1.5 tonnes of olives. Some lye was inserted to prevent bruising, the olives were added then the tanks were filled with lye. A grass matting cover was placed on the surface of the lye and over it a slatted wooden cover held in place by a few heavy stones. These pressed the covers down so that the olives were not exposed to the air during the process which continued until it had penetrated 2/3 of the flesh in the Manzanilla variety and just over 1/2 in the Gordal variety. From time to time the olives were cut open longitudinally to determine the degree of penetration of the lye. Another method of checking was to flood a sample of olives with a 1% solution of phenolophthale in 95° ethanol – this causes the flesh affected by the lye to turn pinkish. The same procedure is still applied today in many small-capacity plants in Spain.

In Greece, Argentina, California and in the North African countries, the lye treatment was carried out either in concretetanks or in the same containers in which fermentation was to take place, the only difference being the concentration of the NaOH in the lye which used to be very dilute with just 2% or even less NaOH. Under such conditions, the treatment lasted up to 16 hours and even then penetration of the lye in the olives was not uniform. Experience has now shown that the sodium hydroxide content of the lye must be the greatest the olive fruit can tolerate without any adverse consequences on the skin and flesh although the actual quantity depends on the olive variety.

In the processing plants of the large multinational companies in Andalusia today efforts have been made to limit environmental pollution. Lye treatment is now carried out in spherical polyester tanks at ground level and of the same shape and capacity as the fermenters which are usually below ground.

Another revolutionary development in this process is the re-utilisation of the spent lye solution by mixing with it fresh, high-density sodium hydroxide solution thus building up its strength to the original level. Some technicians consider that, in this way, the same load of lye could be used throughout the processing season.

In such cases, when one load of lye has been spent, instead of rejecting it as used to be done in the past, it is transferred to another vat and mixed with a fresh NaOH solution to be used to remove the bitterness of the next batch of olives. The determination of NaOH in the spent lye is carried out volumetrically using standard hydrochloric acid and helianthin as the indicator. The indication given by the Haumé hydrometer refers to all water-soluble substances, including the NaOH, that increase with reuse of the solution. It is important to take into account the fact that the spent lye after being reused a number of times gains an osmotic pressure equal to that of olive fruit juice. It therefore seems strange that a lye so rich in soluble solid substances should remove oleuropein out of the olive flesh. However, the ability of the spent lye to remove bitterness remains practically unaffected during the whole period of olive processing. This phenomenon quite possibly indicates that the rebuilt lye breaks down the oleuropein



Fruit undergoing lye treatment in vats (Photograph by courtesy of Agro-Aceitunera).

molecule in situ (in the flesh) and the resulting products are subsequently extracted by the washing water. In any event, the reuse of lye means that industries save money and reduce environmental pollution.

Washing with water

Washing is carried out as soon as the alkali reaches the desired depth in the flesh and aims to reverse the process of penetration of the lye solution and to remove any residual lye.

Washing must last just long enough to achieve these two aims without removing all the fermentable substances, minerals, micronutrients, etc. from the flesh and to leave sufficient traces of lye to create an effective buffer system in the brine.

Cruess of the University of California (1924)[16] was the first person to suggest that olives should be washed intensively for 2-3 days with changes of water every 3 to 6 hours during the day and every 10 hours at night. However, since the washing water in some regions of California was slightly alkaline[69], the net result of such extensive washing was that the fruit flesh was left without nutrients. Prolonged washing was also applied to Konservolia olives in Greece but this variety is inherently deficient in fermentable substances and, as a result, since all the nutrients were washed out, fermentation became impossible.

Conversely, mild washing lasting 10-12 hours with one or two changes of water was shown to leave larger quantities of residual lye which was then transferred to the brine. The initial pH of the covering brine was 8.5-9 or even higher and inhibited the formation in it of the desirable lactic acid bacteria. In addition, the lye residue in the brine set up a strong buffer system that meant it was difficult for the pH value to drop as normal in lactic acid fermentation to 3.8-4 at the end of processing.

For the above reasons, the traditional washing scheme, as applied in Andalusia for many decades, has proved to be the most suitable.

This washing process lasts 12-14 hours, during which the water is changed three times. The first wash lasts just 15 minutes and aims to rinse off most of the lye left on the skin of the olive fruit. The second wash lasts 2 hours and the third for 10-12 hours (that is, overnight). This scheme for washing has been gradually adopted by all olive-producing areas (Latin America, North Africa, USA).

In the large green olive processing plants of Andalusia, washing generally uses two loads of water and sometimes just one. The excess soda transferred to the brine is neutralised with acids such as HCl or acetic or lactic acid but customarily by passing a CO_2 current through the load of olives which reduces the pH to 6.2-6.5. With this system of reduced washing, the volume of effluents is reduced and disposal is relatively easy because the organic load is much smaller.

Packaging of olives after washing

Immediately after washing, the olives used to be placed in barrels, covered with brine and rolled into the fermentation yard to undergo lactic acid fermentation. In small plants fermentation is still carried out in wooden or plastic barrels which in Andalusia had a standard capacity of 500 Kg and were named *bocoys*.

To fill the barrels the upper hoops were loosened, the cover removed and the washed olives were added up to the level of the inside surface of the cover which was then replaced, with the hoops being tightened and brine being poured in immediately.

In California, the washed olives were initially packed into small wooden barrels (about 275 pounds of olives plus 20 gallons of brine) but these were later replaced by wooden vats made of red-wood and containing as much as 5 tonnes of olives. The same vats were used in Latin America (Argentina, Venezuela) and in Greece until they were eventually replaced by rectangular concrete tanks holding up to 20 tonnes of olives. However, it was difficult to achieve anaerobiosis inside these tanks and they were ousted by polyester globes holding 9,500 Kg of olives in which it is easy to exclude oxygen. Whatever the type of recipient, the olives are covered with a brine of 6-10 Bé or even 11 Bé depending on the fruit variety.

The lactic acid fermentation of green olives

When successful, lactic acid fermentation is the key to good quality and organoleptic characteristics in the end

Rolling a bocoy. (Photograph by courtesy of F. Corchero).

product as well as to good preservation during storage and marketing.

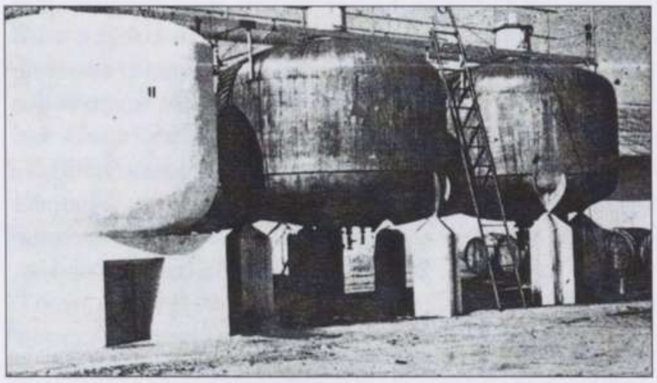
The prerequisites for efficient fermentation are:

- Anaerobiosis in the recipients containing the olives covered with brine.
- Sufficient sugars in the olive fruit after lye treatment and washing to support the growth of lactic acid bacteria. If insufficient, the brine has to be enriched.
- A mixed microbial population in the brine in which the desirable lactic acid bacteria, by means of appropriate manipulation, end up predominating.

• Anaerobiosis

Traditionally, anaerobiosis was achieved by filling each barrel with brine daily but anaerobiosis was never complete throughout the 24 hours, the process was costly in labour and there was a continuous loss of salt and lactic acid through leakage.

Later on, wooden covers in two or three pieces were used for both wooden and concrete tanks that exactly fitted the surface of the recipient. They were filled with hot paraffin wax that solidified preventing the passage of air but, even so, anaerobiosis was not complete.



Above-ground polyester vats for outdoor fermentation.

The problem of anaerobiosis was eventually solved at low cost by using plastic globes that narrow progressively and end in a manhole. Airtight closure is achieved with a floater on the surface of the brine touching the inner walls of the globe.

Fermenting green olives are more sensitive than black olives to incomplete anaerobiosis, with oxidative microbes forming a membrane on the surface and oxidising firstly the sugars in the brine and then the lactic acid. Under such conditions, total acidity diminishes and the pH value increases to such an extent that proteolytic microbes eventually spoil the product.

Table olive processors know from experience that a leathery membrane of oxidative microbes is the starting-point for severe deterioration.

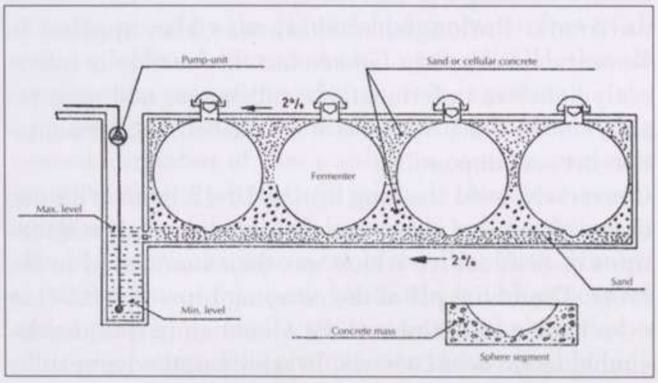
• Fermentable constituents

These are the sugars that are left in the flesh after the lye treatment and washing, half of which have passed into the brine when equilibrium is reached. If such constituents have not remained in the flesh, fermentation and production of lactic acid in the brine will not take place.

The quantity of fermentable constituents depends on the olive fruit variety, the soil and climate conditions of the region, cultural practices, etc. If there is insufficient fermentable matter for normal fermentation, then either a syrup (cerelose) has to be added to the brine during fermentation or lactic acid must be added at the start and finish of fermentation.

• Microbial population

This is settled in the brine when it is poured over the olives and consists of atypical microbes that are unrelated to each other. However, under normal conditions, the desirable lactic acid bacteria predominate over all



Processing of green olives.

the other groups and bring about the necessary fermentation.

Inoculation of the brine with pure cultures of lactic acid bacteria or with brine from actively fermenting vats encourages fermentation but such manipulation is usually only necessary in newly-established factories or for experimental fermentation.

• Characteristics of the lactic acid bacteria causing fermentation

The lactic acid bacteria are non-sporulating, gram-positive and do not react with catalase. There are four genera – *Streptococcus*, *Leuconostoc*, *Pediococcus* and *Lactobacillus*. There are two types of physiology: homofermentative which in theory converts all the sugars into lactic acid and heterofermentative which converts half the sugars into lactic acid, and the rest into CO_2 and alcohol or acetic acid.

Researchers have been able to isolate representatives of the four genera from the brine of green olives. It has been shown that the species of greatest interest for olive fermentation are *Leuconostoc mesenteroides*, *Lactobacillus braevis*, *Lactobacillus buchneri*, *Lactobacillus plantarum*, *Lactobacillus casei* and *Lactobacillus delbrueckii*[52]. The first three are hetero- and the last three are homo-fermentative. More recently, the following species have been isolated from fermenting olives in polyester globes – *Leuconostoc paramesenteroides*, *Pediococcus urinae equi* and *Streptococcus lactis*.

Lactic acid bacteria have the following characteristics:

- They grow under anaerobic conditions in the olive fermenters where the growth of oxidative microbes is inhibited by the lack of oxygen.
- They multiply when the salt content of the brine is 8% and transform the fermentable constituents into lactic acid. The lower the salt content of the brine, the more active they become with maximum activity taking place in olives in plain water.
- They are settled in the brine and become active when the pH of the brine reaches 6.2-6.5 (slightly acidic) and only certain of them start to grow at neutral pH or when the brine is slightly alkaline. The industrial process is based upon the whole group of them when the pH value is slightly acidic.
- Their growth and activity are inhibited when the pH value drops to 3.8-3.5 and total acidity reaches 1.2% or more.
- Those that are responsible for the fermentation of olives are mesophilic and as such do not grow at all at temperatures below 15°C. They grow and ferment slowly at 15-18°C, ferment well at 19-23°C and show maximum activity at 23-27°C. In general, at temperatures above 30-32°C they are practically inactive.

• Fermenting green olives in brine

The fermentation of green olives is a purely biological phenomenon resulting from the competition between the different microbial groups in the initial mixed microflora. It is essential that the technicians in charge of the process establish inside the fermenters the necessary conditions for the desirable lactic acid bacteria to be able to predominate over the other undesirable groups of microbes.

- The olives must be packed into recipients of varying capacity and covered with brine with the highest possible salt content without causing the fruit to shrivel. Bear in mind that large-fruited varieties tolerate less salt in the brine than small-fruited ones.
- Total anaerobiosis must be achieved as early as possible in order to inhibit the oxidative microbes and encourage only the fermentative microbes which include the desirable lactic acid bacteria.
- The brine must be acidified at the start either by adding organic or inorganic acids or by passing a CO_2 current through the olive load. A slightly acidic environment (pH 6.2-6.5) encourages the establishment of lactic acid bacteria and lower initial pH values may inhibit their growth.
- The brine should be enriched with extra fermentable substances if these are insufficient. Cerelose syrup gives good results, as does pure saccharose which is currently being used with success by the table olive industries in Andalusia.
- Regular checks should be carried out on total acidity (volumetrically) and the pH value (ionometer). If the course of fermentation is regular, total acidity increases progressively and the pH value decreases correspondingly.
- The salt content of the brine should also be regularly checked. Bear in mind that it drops at the start until equilibrium is reached between the olives and the covering brine. Then solid salt should be dissolved in the brine by circulating it with a portable pump until the salt content rises from 5-5.5% to 8% at the end of fermentation.
- The brine temperature must be maintained at between 15°C and 27-30°C throughout fermentation. It can be prevented from dropping below 15°C by passing part of the brine through a portable heat exchanger. Under such conditions, fermentation will not be interrupted until all the fermentable substances have been converted into lactic acid, with total acidity being stabilised by the end of the process at around 0.8-1%.

The procedure is successful once the lactic acid bacteria gain the upper hand over the other groups of microbes by which time fermentation is unlikely to be interrupted and there is little chance of spoilage.
It must be remembered that only yeasts coexist with lactic acid bacteria and break down some of the sugars by converting them into alcohol and CO_2. They do not generally create any special problems as long as the lactic acid bacteria predominate.

- Methods to ensure correct lactic acid fermentation

These are as follows:

- The temperature of the brine must be maintained between 18ºC and 30ºC throughout fermentation.
- In cases of blocked fermentation(6), when yeasts predominate over the lactic acid bacteria, if sugar is added this only aggravates the problem. The brine has to be rejected and replaced by new brine containing dissolved fermentable constituents plus pasteurised tomato or orange juice that enriches it with micronutrients (aminoacids, minerals, vitamins, etc.). The brine must also be inoculated with a pure culture of lactic acid bacteria or with brine from an actively fermenting vat.
- Extra fermentable substances must be added to the brine if insufficient quantities have been left in the flesh after lye treatment and washing. The amount added must be sufficient to give through fermentation a total acidity in the brine of 0.81% lactic acid. The necessary quantity is added in the form of corn syrup (cerelose) or pure saccharose at the stage of complete activity of the lactic acid bacteria and never at the end of fermentation. Before the addition of fermentable substances, a microscopic examination or a culture of a brine sample is indispensable to ensure that the lactic acid bacteria will predominate over the yeasts. It is advisable to add half of the quantity decided upon with the rest being added after one week or more and only when it has been seen that total acidity has increased.
- In certain cases, the olive load must be inoculated with a pure culture of lactic acid bacteria or with brine from a normally fermenting vat.
- In two cases, the brine has to be acidified: at the beginning of processing until a pH value of 6.2-6.5 is reached, and at the end when acidity is below 0.8-1%. In the first case, a current of CO_2 is passed through the load of olives and in the second case lactic acid is added. However, it is more economical to add cerelose during active fermentation.
- The salt content of the brine must be continuously monitored. At the start the brine has a high salt concentration but this drops as equilibrium is reached between the brine and the flesh of the fruit. This is the lower salt level that is kept constant through the whole period at low temperature. Then the salt content is gradually increased by dissolving solid salt in the brine in early spring and during the summer to reach 8%. Exceptionally, when the olives are to remain in the vats during the summer, the salt content of the brine is raised to 8.5% to prevent the growth of Propionibacteria (which would lead to *zapatería*).

Maturation of fermented olives

The fermented olives are kept in the vats covered with the mature brine for a period of 30-40 days or up to 2 months in order for their organoleptic qualities to develop fully. Maturation is more necessary for olives that have been fermented for a short period of time.

Sorting and size-grading

The fermented olives are pumped out of the vats, separated from the brine and placed on conveyor belts from which all the defective fruits are removed by hand. The firmness of the flesh is measured and any olives not having the typical greenish-yellow colour are removed with the aid of an electronic eye.
Size grading is carried out using a grader based on progressively diverging cables. The olives move along two of these and fall when their diameter is smaller than the distance separating them. There are usually nine standard sizes.

Stoning and stuffing of fermented green olives

It is traditional in Spain to stone fermented green olives and stuff them with red pepper (pimento) or onions, anchovies, capers, etc.
The same process was also applied in other olive-growing areas such as California, Greece, North Africa, etc. but never became commercially significant.
Initially, both processes were done manually but now they are done by machine. The peppers used to be skinned, washed, salted and cut into strips for stuffing the olives. But this process gradually evolved and now they are ground into pulp, packed into 5 Kg cans and subjected to thermal treatment. The paste is then mixed with guar gum and sodium alginate, homogenised and left to solidify in layers. It is then fed into a machine that both stones and stuffs the olives. While the end product does not have the taste and aromatic characteristics of hand-stuffed olives, such machines have made it possible to continue to manufacture this product which otherwise would have become impossibly costly.

Final packaging for retail sale

Once stuffed, the olives are packed either into small glass containers or 5 Kg glass or tin containers. These are filled with fresh brine acidified with lactic acid and having a salt content of 6% and a pH of 4 or less. Mature brine used to be used for filling but it formed an unsightly sediment so is no longer used. Pasteurisation is either omitted or carried out at 80ºC for 5-20 minutes in the case of glass jars and for 12 minutes in the case of cans. Fermentation of the red pepper sugars does not take place so no sediment is formed. In certain cases small quantities of citric acid are added to the packed product. These olives are exported worldwide and are generally consumed as aperitifs to accompany alcoholic drinks.

A large proportion of Spanish-type green olives is left unstoned and is packed in the same way as stuffed olives.

Small-capacity processing plants still use genuine pepper that has been fermented, cut into strips and stuffed manually into stoned olives. Although the cost of production is excessively high, these olives have an excellent flavour, aroma and eating qualities.

UNTREATED BLACK OLIVES

INTRODUCTION

Untreated black olives are olives that are left on the tree until ripe when they turn purplish-black or jet black. They are then immersed in concentrated brine to remove most of their bitterness. According to the CODEX/IOOC Standards they can be preserved in brine, by sterilising or by the addition of preservatives. However, in practice they are nearly always preserved in concentrated brine.

They differ from treated black olives in that their black colour is due to the anthocyanin content of the flesh and not to phenol oxidation in an alkaline environment. Their flesh is also softer.

The international statistics do not distinguish between the two types of black olives. Average annual production during the six-year period from 1986-87 to 1991-92 reached 314,000 tonnes, that is, 36% of the world total of table olives. In recent years, greater quantities of treated black olives are being produced than of untreated olives and this trend seems likely to continue.

According to the bibliography, untreated black olives in brine take second place in world trade after black olives in dry salt[37]. They are highly prized by consumers and processors because:

- the method of preparation is relatively simple in comparison with other trade preparations of olives;
- the final product conserves the flavour and aroma of the original fruit;
- the processing methods are natural;
- according to growers, since the fruit is left on the tree until completely ripe, maximum yield is ensured.

COUNTRIES PRODUCING UNTREATED BLACK OLIVES

The main producer country for untreated black olives is Greece because the darkening of olives with alkali has been prohibited by law since 1939[9, 26]. So, for more than fifty years, Greece had the privilege of seeing its name linked to untreated black olives in brine. Other countries producing relatively large quantities of this trade preparation are Turkey, the Middle East countries (especially Syria and, to a lesser extent, Jordan and the Lebanon), Yugoslavia, Cyprus, Egypt, etc.

As with fermented green olives in Spain, untreated black olives are the most traditional Greek trade preparation. The variety used is primarily Konservolia, followed by certain dual-purpose varieties such as Kothreiki and Hegoumenitsa (both of which are considered by many researchers to be clones of the Konservolia variety), Kolovi, Adrammytini, etc. Even today, many Greek olive-growers believe that olive fruits gain in weight if they remain on the tree until completely ripe although a recent study has shown that maximum weight is when the fruit colour is deep red.

The Konservolia variety gives the ideal fruit for this trade preparation because of its incomparable natural and chemical characteristics[12].

THE HISTORY OF PROCESSING UNTREATED BLACK OLIVES

Untreated black olives have been produced in Greece for centuries, processing being based upon experience and skill. Growers left the fruit on the tree until ripe or even overripe but aimed to harvest it before the first frosts because otherwise the fruit shrivelled and would only be fit for oil production[14].

Until the early fifties most growers were also processors and transferred the ripe fruit to their homes where they stored it in wooden vats in their cellars or ground floors. The vats were made of good quality wood and were shaped like truncated cones 2-3 m high with a valve at the bottom for draining the brine. Capacity varied between 500 Kg and 5-6 tonnes.

The olives were placed in the vats as soon as they arrived from the orchard. Preliminary sorting, size-grading and washing were unknown procedures, because of lack of room and facilities and also because of ignorance. The vats were filled up gradually over a period of many days or even weeks, depending on the rate at which harvesting was carried out. During this period, the vats remained open and the olives were covered with a 10% brine. When full, they were covered with sacking and a wooden grating held down with a few heavy stones to keep the olives continuously immersed. Anaerobic conditions did not exist and the brine floated over the rudimentary cover supporting the growth of oxidative microbes in the form of a slimy membrane one centimetre or more thick.

The salt content of the brine, due to osmotic phenomena at first and to diffusion later, dropped to 6-7% and sometimes to 4-5% during the winter. It took a long time for equilibrium to be reached between the brine and the flesh because the olive fruit tissues remained alive for a certain time (approximately 50 days according to Spanish researchers)[39]. Solid salt was added in early spring to build up the strength of the brine to 12-14%. The olive fruits usually shrivelled and became decidedly salty. The high salt content, however, was the only way of preserving the product. Recirculation of the brine was an unknown process and nothing was known about the physical and chemical changes taking place in the olive flesh. Nor was anything known about the composition or the action of the thick membrane that formed on the surface of the brine.

The olives were left in the brine, which was dilute at first but dense later, until the end of the summer during which time they lost most of their bitterness[40]. At the same time, the olives were pickled, losing most of their acridity and developing their flavour, aroma and eating qualities.

The olives were then removed from the brine and spread on tables to be exposed to the air for 2-3 days in order to oxidise the colouring substances in the olive flesh. The final product was slightly shrivelled, perceptibly salty and slightly bitter. The emptying of the vats was a laborious, time-consuming task carried out by lowering baskets into the vats which were loaded by a person actually inside the vat. Obviously, even basic hygiene was difficult to achieve. Today such vats have been eliminated and, if used, unloading is done by mechanical means.

Before final packaging, the olives were sorted by hand and then size-graded mechanically.

They were then placed in rectangular tins that were lacquered inside and that held 15-20 Kg of fruit. Wooden barrels holding 50-130 Kg of processed olives were also used. In all cases the containers were filled with fresh brine at a lower concentration than the mature brine. Once packed, they were sent to both domestic and international markets under the designation «Untreated Greek black olives in brine». Their colour was black to a reddish-violet and their organoleptic qualities were excellent. Their characteristics have always been highly prized by consumers and they have a firm place on the market.

In most cases, the olive-growers used to sell their processed olives to packers with rudimentary installations for exposing the fruit to oxidation, sorting, size-grading and packaging.

THE FINDINGS OF RESEARCH INTO UNTREATED BLACK OLIVES

The first efforts to place the processing of untreated black olives under control were made in the fifties and sixties. The first five cooperative factories were set up in Greece in 1952 to process Spanish-style green olives using wooden vats or concrete tanks. Occasionally, the same factories started to store and process black olives in parallel with green olives and this was the start of industrial production of untreated black olives. During the fifties, almost 80% of the total production of table olives was stored by olive-growers with the remaining 20% being transferred to industrial plants. By 1972, the percentage had decreased from 80% to 50% and today the percentage left in the hands of olive-producers is just 20-25% of the total.

The first research work into untreated ripe olives was undertaken in the mid-sixties[11, 2]. It aimed to determine the nature of black olives, their composition and what measures would be appropriate to improve their keeping and eating qualities. Samples of mature brine and of the membrane that formed on the surface were collected and analysed[4, 52].

The most important findings of this research was:

- The pH values of brine commonly lay between 3.9 and 7.1 although it ought to be about 5.5 with a total acidity of 0.1-0.2% in the absence of any type of fermentation.
- The volumetric acidity varied from 0.1% to 0.5% indicating that in some vats some fermentation had taken place.
- The protein content of olive flesh and brine was found to be low and equal to 12.5-65.4 mg per 100 cc of brine but this was sufficient to support the growth of both desirable and damaging microbes if other factors were favourable.
- The salt content varied from 8% to 19.3% indicating that each olive-grower applied his own processing system. Salt content above 8-10% caused shrivelling and deterioration of the organoleptic qualities making the olives excessively salty.

- The fermentable substances varied from traces to 0.42% indicating that at certain stages microbes had developed and broken them down.
- The tannin content in the brine was high, varying between 1.5% and 2.5%.
- The buffer capacity of the brine presented a maximum pH value of 3.4-3.9 and a minimum pH value of 7.25 which is similar to that in other trade preparations of table olives. However, the strength of the buffer capacity was relatively low due to the low degree of acidity in the brine and to the complete absence of residual lye.

In conclusion, the preservation of untreated black olives on family-owned, rural farms was based exclusively on the high salt content of the brine. The other two factors (acidity-pH and anaerobiosis) were not involved.

Reducing the salt content of the brine below 10% was not advisable because it would lead to the deterioration of the product and in any event the nutrients in the excessively salty brine supported the growth of oxidative microbes in the form of a thick superficial membrane that sealed the surface of the brine and isolated it from the environment.

Further research studied the composition and role of the membrane. Its conclusions were as follows[52]:

- The membrane comprised a network of hyphae of higher fungi, the holes of which were interspersed with cells and pseudomycelia of yeasts, bacteria cells and hyphae of streptomycetes.
- Yeasts, fungi, streptomycetes and bacteria were isolated from patches of membrane. The genera of the yeasts were Pichia, Hansenula, Debaryomyces, Candida, Rhodotorula, Trichosporon, Torulopsis and Kloeckera; the genera of the fungi were Rhizopus, Penicillium, Aspergillus, Paecilomyces, Hormodendrum, Alternaria and Monascus and the genera of the bacteria were Micrococcus and Bacillus.

Lactic acid bacteria were not isolated and among the fungi the Penicillium and Aspergillus genera predominated. More specifically, the Penicillium roqueforti found in Roquefort cheese was found in most of the samples. Of the yeasts, the Candida pelliculosa species and certain species of Trichosporon were shown to tolerate the highest salt concentration of 22%.

Most of the fungi were shown to be pectinolytic and to soften the tissues of the olives, whereas the micrococci and some spore-forming bacilli produced small quantities of acids in the early stages of processing. All the membrane microbes were found to be oxidative and found their carbon source in the acids of the brine as well as in the fermentable substances, resulting in the increase of the pH values. Such changes pave the way for the development of the highly undesirable proteolytic bacteria but these are highly sensitive to salt and only grow when the strength of the brine drops to low levels. This fact justifies the addition of excessive quantities of salt to the brine by processors to reach 10% or even 18% in some cases in order to avoid butyric fermentation, zapateria, etc, which are generally caused by such proteolytic bacteria. Many of the membrane microbes proved to be lipolytic (all fungi, most yeasts, the micrococci and certain spore-forming bacilli), secreting lipase, the enzyme that is responsible for the hydrolysis of a part of the triglycerides and subsequent rancidity through the action of oxygen on the free fatty acids in the olive flesh. Finally, the streptomycetes were blamed for the 'earthy' smell of certain batches of untreated black olives.

To avoid the above adverse consequences, it was recommended to olive producers and to all those engaged in any way in the production of untreated black olives that they should secure anaerobic conditions in the recipients in which olives were fermented and packed using the techniques described on page 322 to prevent the development of the surface membrane.

This membrane was shown to be the basic cause of severe deterioration in untreated black olives in brine but, in cases where it was difficult to secure anaerobiosis, it was recommended that the membrane should be considered an unavoidable evil and left intact. If removed, a new one would form within a few days and the deterioration of the product would be speeded up.

Other research showed that untreated black olives immersed in brine and placed under strictly anaerobic conditions might undergo complete lactic acid fermentation[11]. But the final product had a cherry-red colour because of the low pH value and a perceptibly acid taste so its quality characteristics were incompatible with the traditional trade preparation of untreated black olives in brine.

The above results[3] were presented in the international seminar on olive cultivation held in Perugia (Italy) in 1967. The techniques for this type of preparation and the improvements proposed to Greek processors were published in the seminar's proceedings and have since been adopted by other olive-producing countries.

The methods were shown to be simple and straightforward leading to an end product with better organoleptic characteristics than most other trade preparations.

At the time, Spain showed interest in this type of product and increased its production of untreated black olives in brine from 1,000 to 12,000 tonnes within the first seven years after the seminar[27] although, for reasons to be explained below, it was later to decline.

THE PREPARATION OF UNTREATED BLACK OLIVES IN BRINE

The traditional method of processing untreated black olives in brine, as revised in the light of research work conducted over approximately 40 years and of industrial experience since the fifties, is presented below in the form of a flow sheet.

Harvesting of the olive fruit
↓
Transport to the factory
↓
Placement of olive fruits directly in the tanks
↓
Filling up with water
Replacement of water with brine
Fermentation – Removal of bitterness
↓
Removal of olives from tanks
↓
Sorting – Size-grading
↓
Return to tanks
↓
Removal for packing
↓
Retail packaging

Raw olives of the Konservolia variety, when properly processed, give table olives of excellent quality, the bulk of which are exported.

When olives from dual-purpose varieties (Kothreiki, Egoumenitsa, Adramyttini, Kolovi, Megaritiki, Agouromanacolea) are used, the quality is not so good and they are sold at lower prices and are mostly consumed in local markets. Small quantities are exported to Third World countries.

The details of each step are as follows:

Raw material

Harvesting begins at full maturity or a little before (from 15 October to end December). The colour varies, depending on the region of production and the stage of maturity, from reddish-black to jet black.

Ripe olives are very sensitive to damage. Their flesh is softer than that of green olives and is easily bruised or scratched.

In addition, ripe olives are generally harvested in bad weather conditions, often when it is raining, so they frequently end up muddy or dirty. And still today as much as 25% of the harvested olives are stored in the rudimentary installations of olive growers without running water or any type of machinery or drainage system for the effluents.

The natural colour is the main quality factor for this type of preparation which is the reason why olives are left on the tree as long as possible. However, harvesting should take place before the first frosts which would kill the fruit tissues. The fact that the olives are left unpicked for as long as possible exposes them to late attacks by the Dacus fly and this factor, together with frost damage, are the two main problems for producers of this type of olive. In addition, the late harvest upsets the physiological activity of the olive tree and it consumes all the available nutrients. Since it sets fruit on two-year old wood, it has no vitality or nutrient reserves to set fruit the following year. Thus in olive orchards producing black olives, the phenomenon of alternate bearing is seen at its worst.

Harvesting

This is carried out by hand, by milking off or by knocking the fruit from the tree.

Since black olives are more delicate than green ones, harvesting has to be carried out by hand and is therefore very costly. In Greece, Algeria and other countries it is also common to knock the trees with poles to loosen the fruit but this damages both the fruit and the trees and is, in fact, illegal in Algeria. Growers still resort to this method in an effort to reduce costs and also when tree canopies are too large for convenient hand picking. Harvesting by hand is economical when the tree canopy is of medium to small size and is accessible to pickers standing on the ground or on short ladders. It is being facilitated in new olive tree plantations.

In black olives, the colour and compactness of the flesh are inversely related so that olives with a good colour have a poorer texture than lighter ones and vice versa.

If all the harvest is carried out at once, part of the olives are green or reddish. These are processed separately and sold as olives turning colour in brine. This is a distinct type, although it is in fact a by-product of untreated black olives, and is sold at a lower price.

Transport

The olives are placed in stacking crates with holes for aeration. They hold 20-35 Kg of fruit. Baskets with a capacity of 45-50 Kgs are no longer used because they caused too much damage to the fruits.

The crates are then loaded onto trucks or trailers to be taken to the factory. Transport must be as quick as possible so, if the processing plant is far from the orchards, travel should take place at night with plenty of air circulating through the olive load.

Placement of olives in tanks

On arrival from the orchards, the olives fall directly into the tanks (after first taking a sample). Bruising of the first olives to fall is prevented by a layer of water at the bottom of each tank. Sorting and size-grading is omitted in large plants but in some, the bruised, misshapen, insect-damaged and blemished fruit is removed first. The olives are then washed to remove soil and other impurities and are introduced into the fermenters and covered with brine. The salt content varies between 6 and 8% in the case of green-reddish olives and 8-10% for black ones. The fermenters are closed hermetically in order to secure complete anaerobiosis.

It is also customary in some factories for olives to be kept in water for 6-8 days instead of being washed in water under pressure. The water is then rejected and replaced with brine. This method has the advantage of improving the firmness of the flesh, the intensity of colour and of reducing shrivelling in the next stages of processing. However, such storage in water is risky and, although a standard technique for the Kalamata variety, it has been shown that lactic acid bacteria grow in the covering water and ferment the sugars that diffuse out of the flesh, creating acidity as high as 1% (1 g of lactic acid per 100 cc of covering water) and promoting subsequent spoilage by gram negative bacteria. Spanish researchers recommend immediate washing with water under pressure[19, 20].

Fermentation

The preliminary treatment involves the immersion of the olives in concentrated brine under practically complete anaerobiosis.

The salt acts as a dehydrating agent and transfers part of the water-soluble constituents of the flesh to the brine. It also hinders the development of proteolytic bacteria. These are sensitive to high salt concentrations and tolerate much less salt than lactic acid bacteria. If proteolytic bacteria predominate (when the brine is very dilute), they secrete proteolytic enzymes, break down the proteins into bad-smelling by-products (NH_3 = ammonia, H_2S, indole, etc.) and cause severe deterioration to the fruit. Lactic acid bacteria can tolerate salt concentrations of up to 8%. The salt also helps to develop good organoleptic qualities in the final product and preserves the olives throughout the different stages of processing.

Of critical importance for normal fermentation and the removal of bitterness is the salt content of the brine. It has to be as high as possible without damaging the fruit[57]. Tolerance depends on the olive variety, the region of cultivation, the size of the fruit which is inversely related to its tolerance and the type of cultivation (olives from non-irrigated orchards are more resistant to salt than those from irrigated orchards).

Inside the tanks or vats, the salt moves from the brine to the fruit and the water-soluble constituents move in the reverse direction. According to the Spanish bibliography[27], equilibrium is reached in approximately 50 days because such olives are not subjected to lye treatment and the cytoplasmic membranes remain alive longer.

Due to the exchange of salt and water-soluble constituents between the brine and the flesh, the original salt strength of the brine drops from 8-10% down to 6-6.7% and in some cases even lower. It then remains at this level until early spring, favouring the development of the desirable lactic acid bacteria. However, during the spring and summer, the salt content of the brine is gradually rebuilt up to its original strength of 8% maximum.

High acidity is undesirable in the case of untreated black olives and increasing the salt content of the brine is an easy means of inhibiting the growth of lactic acid bacteria. For this reason, some processors used to spread additional salt on the top of the wooden vat covers which were disassembled so that the brine flowed over the top taking the salt with it.

The practice of allowing fungi to develop in order for them to consume sugars or acids is not recommended and is no longer applied, especially because most fungi in the brine secrete mycotoxins. It is necessary for the brine to be homogenised by recirculating it with a portable pump, particularly in large-capacity vats.

In brine with 8% or less salt, microbes of three types can develop – aerobic or purely oxidative, strictly anaerobic and others which can be either aerobic or anaerobic. Development of the oxidative microbes is impeded by anaerobiosis while that of the strictly anaerobic microbes (mainly clostridia) is impeded by the increase in salt content and the acidity.

The microbes of interest for untreated black olives, in addition to the yeasts, are the lactic acid bacteria which belong to the third category. Spanish researchers report that fermentation in ripe olives is caused exclusively by the yeasts[27,37,35]. Coccus-type lactic acid bacteria were isolated exceptionally from the brine of only one variety (Hojiblanca) but it is not clear how an appreciable degree of acidity is formed since yeasts do not form acids and, on the contrary, many of them utilise acids as a source of carbon for their development[45].

According to the Greek bibliography[10], untreated black olives, under the conditions described above, undergo typical lactic acid fermentation. The difference between the two types of fermentation is quite probably due to

Underground polyester vats for fermenting black olives.

the differing concentrations of polyphenols in the flesh of the various varieties.

Anaerobiosis inside the containers used for storage and fermentation is the main prerequisite for success because it prevents the development of oxidative micro-organisms and the formation of a highly undesirable membrane on the surface of the brine. In general, untreated black olives are less sensitive to anaerobiosis than green olives. It is important to note that the matter of anaerobiosis only started to be taken seriously into consideration by the table olive industry in Greece as from 1952. The solution eventually found was to use the same polyester globes as are used for green olives but beneath ground level. The benefits they provide are that the temperature remains more stable throughout the process, processing is easier and more economical and their outdoor location reduces the cost of factory construction. The drawbacks are that any leakage is difficult to control, repairs to the globe walls are more costly (although the tanks in general are very sturdy) and rainy weather may prevent necessary tasks from being carried out.

The large-capacity tanks built of reinforced concrete that were used previously have now been replaced because they had several disadvantages. The fact that they contained 10, 15 or 20 tonnes led to excess pressure on the olives, especially if they were ripe. The height of the tanks – up to 2.5 m – made any work difficult and the large openings had to be closed by heavy wooden covers so that anaerobiosis was never complete. The problem of loading and unloading has today been solved by the use of absorption pumps.

The processes involved

When ripe olives of the Konservolia variety are immersed in brine with a salt content of 8% under anaerobic conditions, their cytoplasmic membranes and cells are alive and liberate large quantities of CO_2. The exchange of the constituents between the olive mesocarp and the surrounding brine is delayed because it takes place by osmosis. The salt content of the brine is therefore kept at a high level for a long time and this holds back the development of the proteolytic bacteria that can produce spoilage. The few acids in the olive flesh, however, are partly transferred to the brine so the pH from the start is below 7. This is of particular importance for the rest of the process.

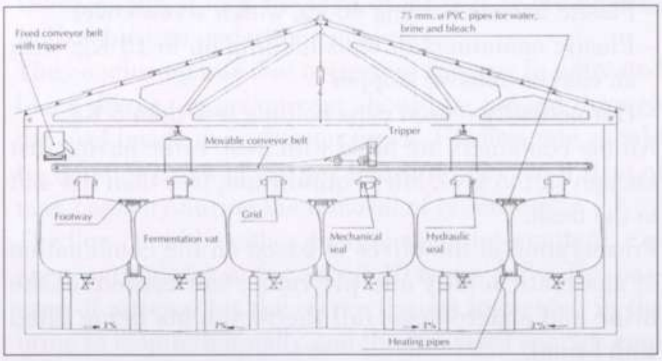
The anaerobiosis prevents the development of oxidative micro-organisms but encourages the development of the Gram-negative bacteria, of the yeasts that encourage alcoholic fermentation and of the lactic acid bacteria that are of importance for de-bittering and fermentation. There is strong competition amongst the three types of microbe because each tries to predominate over the other two.

The phenols from the flesh are partly transferred to the brine and gradually hold back development of the lactic acid bacteria but not the yeasts[67]. In all cases, fermentation starts automatically as soon as the ripe olives are immersed in the brine because of the activity of the combination of flora including fungi, yeasts and bacteria. The small quantity of air present initially seems to support the development of purely oxidative micro-organisms but this soon subsides. During the first stages of processing, large amounts of carbon dioxide are set free which can be attributed to the activity of gram negative bacteria, most of which are Coliform bacilli, and of the yeasts. The Spanish literature claims that much of this CO_2 is produced by the anaerobic metabolism of the olives[21, 26].

Greek researchers have established without question that lactic acid bacteria develop as soon as the ripe olives are placed in the brine[10]. The phenols in Konservolia olives are apparently insufficient to inhibit the growth of these bacteria in spite of the fact that these olives are not lye-treated or washed with water before brine placement. The Spanish literature reports on problems found with the phenols in the brine of untreated black olives[39, 43a, 44].

The carbon dioxide that is set free by ripe Konservolia olives when immersed in brine creates enormous pressure inside the containers, so much so that the wooden coverings are sometimes forced off and the olives and brine overflow.

The initial turbulent fermentation is followed by mild fermentation during which the lactic acid bacteria and the yeasts work in parallel. The acidity is lower than that formed during the fermentation of green olives with



Above-ground fermentation vats.

about 0.3-0.5 g of lactic acid per 100 cc of brine. The pH value stabilises at around 4.5-5.5.

The factors determining the duration of fermentation are the variety of the olive fruit, temperature, the changes and type of microflora, etc. It usually ends towards the end of July or in August and is marked by the disappearance of any cloudiness in the brine and in the sinking of the olives due to their increased specific gravity.

During the early stages of fermentation, the microflora are heterogeneous whereas during the mild phase practically the only microflora present are yeasts and lactic acid bacteria. The latter predominate if the course of fermentation is normal and include *Streptococci*, *Leuconostoc* and hetero- and homo-fermentative *Lactobacilli*. The *Streptococci* appear first because they are sensitive to both high salt content and high total acidity. They are followed by the Leuconostoc, then the heterofermentative *Lactobacilli*, represented mainly by the *Lactobacillus brevis*, and finally by the homofermentative lactobacilli of which the main representatives are the *Lactobacillus plantarum*. The latter is the most resistant of the lactic acid bacteria to salt and acidity.

The typical characteristics of untreated black olives are their blackness and slightly sour taste. To achieve these, fermentation must be as mild as possible and this is done in two ways:

- by increasing the salt content of the brine to over 8% in order to reduce the activity of the lactic acid bacteria;
- by neutralising the excess lactic acid with sodium hydroxide so that the final pH value is not lower than 4.5.

The previous practice of using brine with 10% salt or more, while it impeded lactic acid fermentation, gave a shrivelled end product that was deep black, slightly sour and perceptibly salty. It should be noted that total acidity higher than 0.5% gives the olives a cherry-red colour with a very sour taste and both of these features are considered unacceptable for Greek-style untreated black olives in brine. Some growers and producers, however, use this technique but their olives tend to be popular only with the local population who consume them as a food rather than as an appetiser. They are also appreciated in certain markets such as those of Eastern Europe and the third world.

During processing the olives lose their water-soluble constituents while absorbing salt. The two processes do not counteract each other so that there is always a loss in weight in the olives. This loss is greater in olives from irrigated orchards than in those from non-irrigated orchards and also increases proportionately with olive size. It is claimed in the literature that loss in weight can be as much as 10% but in modern processing it is limited to 2-3% when the fermentation is correctly monitored by competent and experienced technical staff[57].

The Konservolia variety is ideal for the production of untreated black olives because its fruits contain average quantities of fermentable substances, sufficient colouring substances and sufficient polyphenols to permit the growth of lactic acid bacteria. They also have a compact flesh and a thin and resistant skin. Higher concentrations of sugars in the flesh are not desirable because colour and taste would be impaired.

The fish-eye spoilage which used to be a problem for the production of black olives in Spain only occurs when Konservolia olives are processed under rural conditions and in modern industrial installations it rarely arises.

Removal of bitterness

The peculiarity of untreated black olives is the fact that the removal of bitterness is based on the leaching effect of the brine. This is a slow procedure lasting 3-9 months and its main disadvantage is that funds have to be kept tied up for such a long period.

Conversely, olives darkened by oxidation can be ready for the market within one month after harvesting.

There is strong competition in national and international markets between the two types of black olives that are prepared under quite unequal conditions. This must be seriously taken into consideration.

The perceptibly bitter taste of untreated black olives in brine is a quality characteristic that is prized by consumers. Moreover, oleuropein has been shown to be not only harmless for the human organism but even beneficial if consumed in small quantities[58].

There is no question that untreated black olives in brine have the best taste and aroma of all the trade preparations but the cost of producing them is a serious drawback.

The 1939 decree (1891) issued in Greece prohibiting the use of sodium hydroxide for darkening olives by oxidation should be lifted so that both trade preparations of black olives can be produced freely. This would benefit producers and consumers and, anyway, such restrictions seem out-of-place in a free economy.

Size-grading and oxidation

Size-grading is carried out either before brine placement or during the winter when the temperature is low, after which the olives are returned to the same containers where they remain covered with mature brine until required for marketing. They are then removed with the aid of absorption pumps and exposed to air in order for the polyphenols to take on a deeper and more stable colour. This can be done in one of three ways:

- by placing the olives in tanks, covering them with water and introducing compressed air into the mass;
- by spreading the olives over wooden tables;
- by placing the olives in plastic crates with holes in their sides and transferring them from one box to another once or twice a day. (This is the practice in Algeria).

The oxidation process is time-consuming and in the big industrial units is omitted because it is considered that the olives are sufficiently exposed to the air during sorting and size-grading. It is a common belief that oxidation improves the colour in spite of the fact that it remains non-uniform depending on the batch. However, non-uniformity is a quality characteristic by which it is possible to distinguish between untreated black olives and olives darkened by oxidation.

The size categories are established according to the number of olives making up one kilo but they differ depending on the country of origin.

Packaging

These olives are generally packed in one of the following:

Sorting and size-grading freshly-picked olives.

- Plastic barrels holding 40 kg, with a screw cover
- Plastic containers or cans holding up to 13 Kg, with an easy-to-remove stopper
- Hermetically-closed cans holding less than 5 Kg.

All the containers are filled with fresh brine having just enough salt to give, after equilibrium, less than 8% salt to the flesh.

Preservation of the olives is based on the combination of moderate acidity and pH value, salt content of the brine and anaerobiosis (all the recipients being filled with brine).

Thermal treatment is rarely applied and only to small, sealed containers.

The only additive used in 'untreated black olives in brine' is salt. The end product is slightly bitter and has an excellent flavour and organoleptic characteristics. The only disadvantage of this trade preparation is the cost of production.

This type of table olive is prepared in 62 of a total of 69 table olive factories in Greece, of which 27 belong to cooperatives and 42 are private enterprises. The total capacity of the 69 industrial units is 98,400 tonnes of olives.

Production of untreated black olives in Spain

Untreated black olives were first prepared in Spain in 1969, following the Greek method, and total production reached 12,000 tonnes over the next 7 years[28]. The olives used were from dual-purpose varieties such as Lechin, Hojiblanca, Verdial, etc. Fermentation was attributed to the yeasts in the brine in which lactic acid bacteria were found only exceptionally in certain batches of Hojiblanca olives[23].

Spanish researchers tried to improve the firmness of the flesh by immersing the olives in a solution of calcium chloride[29]. To obtain an acceptable colour, the same workers suggested a brine with a pH higher than 4.5. Later research studied the yeast flora that participated in the preparation of untreated black olives[34]. In all circumstances, the Spanish researchers were faced with severe gas-pocket (fish-eye) deterioration. This was attributed to various causes such as gram-negative bacteria, abnormal respiration of the fruit that was still alive when it was submerged in the brine, lactic acid bacteria, etc. It was finally determined that the two yeast species, *Saccharomyces oleaginosus* and *Hansenula anomala* played an important part in the development of this type of deterioration. It was ascertained that the fish-eye occurring in untreated black olives was very different from that in green olives. It mostly appeared in the form of cracks starting at the pit and reaching the skin[31], indicating that there was an actual loss of flesh.

Occasionally, it took the form of air sacs in the flesh as well as blisters under the epidermis.

The conclusion was that to prevent fish-eye in untreated black olives, an air current should be passed through the load inside the polyester tanks. The flow rate should be 0.1-0.5 litres of air per hour and per each litre of tank capacity during the removal of bitterness[32].

The flow could be either continuous or intermittent, e.g. every second day or for only 8-10 hours daily. The passage of air enables the olives tissues immersed in the brine to respire normally and the two yeast species cannot grow under oxidative conditions. The same oxidation procedure is followed for the storage of the semi-ripe olives that are used to produce olives darkened by oxidation.

Sensitivity to gas-pocket formation (fish-eye) seems to be related only to certain olive varieties. The fact that Konservolia olives seem fairly resistant may be due to a physiological characteristic of the fruit or to the activity of certain types of microbe.

In general, however, this type of deterioration has been a barrier to further development of this trade preparation.

Passing the air current through the loaded tanks is an expensive and delicate operation and, for this reason, the Spanish table olive industry has preferred to concentrate on the production of olives darkened by oxidation.

The production of untreated black olives in Turkey

In Turkey, of an average annual production of 93,300 tonnes of table olives during the period from 1986-87 to 1991-92, 90% were untreated black olives in brine[26]. The variety used most is Gemlik, followed by Uslu, Edincik Su, Karamursel Su, Memecik, Edremit, Ayalik and Samanli.

Harvesting starts at the end of November and lasts until early February by which time the fruit flesh is coloured right up to the stone. After transport to the processing installations, most of which belong to the growers themselves, in baskets or crates, the fruit is sorted and packed into tanks in layers with solid salt. The tanks stand on the ground or beneath ground level and sometimes reach as much as 3 m in height. Each holds 10-12 tonnes of olive fruit. The salt added is estimated at 10-12% of the fruit weight and is evenly distributed so that the last layer covers the top of the load. To secure rudimentary anaerobiosis the loaded tanks are covered with a mat and a slat grating held down by heavy stones so that the fruit is continuously pressed downwards and remains submerged in the brine.

After packing in salt, the tanks are filled with water. The bitterness of the olives is removed by the leaching effect of the brine on the oleuropein in the flesh, firstly by osmosis and then by diffusion. The brine flows over the cover and supports the growth of micro-organisms, most of which are oxidative, and these form a leathery membrane. The product is not usually subject to spoilage because of the high salt concentration. It is not known if alcoholic or lactic fermentation takes place.

Loading and unloading of the tanks is done manually and the process of removal of bitterness is completed within one year. The olives are then sorted, size-graded and exposed to the air to improve their colour which is also intensified by the low acidity of the brine.

The olives are finally packed in plastic sachets without brine for retail sale.

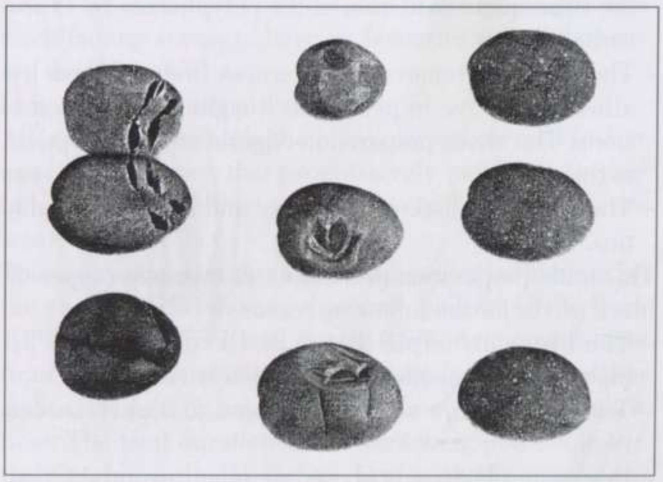
It is estimated that 10,000 tonnes of olives are packed into wooden or plastic barrels filled with brine and sent for export. The end product is decidedly salty and slightly shrivelled but it has a pleasant taste and good black colour due to the low acidity of the flesh.

The production of untreated black olives in Syria

Syria produces 60,000 tonnes of table olives annually[9]. Most are untreated black olives in brine using olives from the Temprani and Sourani variety grown in the northern part of the country. The processing is simple. The fruit is harvested when ripe, washed with water under pressure and packed into 15 Kg cans. These are filled with brine at 10 Bé and sealed. No other intervention takes place. The organoleptic qualities of the end product are good and the only drawback is the non-uniform colour of the olives.

Conclusions

All olive-growing countries produce untreated black olives in brine to a greater or lesser extent. It is clearly the only trade preparation that is easy to prepare both



Microbial deterioration of green olives.

industrially and by olive growers themselves for their own domestic use. The traditional technique continues to be applied today resulting in salty, slightly shrivelled and bitter olives. But these are the olives that the Mediterranean peoples have been eating for centuries. Several problems are involved in the industrial production of this type of olive, the most important today being the high cost of such a slow process.

TREATED BLACK OLIVES IN BRINE

INTRODUCTION

Treated black olives are olives that have been harvested when a reddish colour and subjected to lye treatment to remove their bitterness and to give them a dark black colour. They are generally packed in cans and given a thermal treatment before being sent to the market.

Total production of this type of olive was 314,000 tonnes on average during the six-year period between the 1986-87 and 1991-92 crop years. This represents 36% of total production of table olives. Of the three types of black olive, treated black olives are fast becoming predominant on the market.

The largest quantities are produced in California. The process was taken from there to the countries of northern Africa, mainly Algeria, where French technology was applied. In Spain this is the second most important trade preparation. In Greece, however, it is prohibited by law. The main characteristics of such alkali-treated black olives are:

- The compact texture of the flesh owing to the early harvesting of the fruit
- The uniform dark colour obtained artificially by immersing the olives in a sodium hydroxide solution and the subsequent oxidation of the polyphenols by exposure to the air
- The complete removal of bitterness from the flesh by allowing the lye to penetrate it right through to the stone. The olives prepared in Algeria are an exception to this rule.
- The complete lack of gustatory and aromatic qualities.

This trade preparation predominates over other types of black olives for the following reasons:

- The bitter principle that is disliked especially by high-income consumers is completely removed;
- They have a low salt content and a slightly sweet taste;
- Processing lasts only about one month so production costs are very competitive;
- Presentation in sterilised cans makes them completely safe from the food hygiene point of view;
- They are used more as garnishes than as food, especially as a decoration for pizza;
- They contain proportionately less olive oil because of the partial saponification during the lye treatment. Their taste is therefore smoother and they contain fewer calories per gram.
- According to market research carried out by large multinational companies, they are preferred by young people.

In short, they are considered the table olives 'of the future' because they have no competitors either in terms of production costs or in terms of consumer preference.

PREPARATION OF TREATED BLACK OLIVES IN CALIFORNIA

According to the bibliography, this type of olive was first prepared in California at the beginning of this century[17]. Initially, they were packed like other fruits and vegetables and preserved by a thermal process. However, the temperature of 100ºC (212ºF) that was applied proved to be insufficient because of their alkalinity and outbreaks of botulism were traced to such canned olives. Researchers in the University of California determined

Olives packed in plastic barrels.

that sterilisation had to be carried out at 115.5°C (240°F) for one hour. Today technology has practically eliminated any possibility of botulism in canned foods.

Flow sheet for treated black olives in California

Harvesting
↓
Transport
↓
Sorting and size-grading
↓
Removal of bitterness and darkening by applying dilute lye solutions in between exposure of the fruit to the air
↓
Washing to remove residual lye
↓
Curing in dilute brine for a few days
↓
Sorting and size-grading (if not carried out previously)
↓
Packing in cans
↓
Filling with new brine and sealing of cans
↓
Thermal treatment
↓
Marketing

Harvesting of the olive fruit

This is carried out at the cherry-red stage. If picked before this stage, the end product has a tough texture and poor flavour. The varieties most often used for this trade preparation are Mission and Manzanilla, followed by Sevillana and Ascolana tenera. Canvas buckets are generally used for manual picking from which the fruits are emptied into wooden or plastic crates for transport to the factory.

Preliminary storage of olives submerged in dilute brine

The olives are usually stored in wooden or concrete vats holding 5-6 tonnes for 2-6 months covered with brine with a 5-10% salt content. Attempts are made to achieve partial anaerobiosis but the growth of oxidative microbes is not prevented altogether. It is claimed in the literature that storage before the darkening process improves both the colour and firmness of the texture.

Sorting and size-grading

Both of these processes are carried out before the darkening process. It is considered essential that all the olives in one batch should be of the same size.

Removal of bitterness and darkening

The bitterness is removed and the olives are darkened simultaneously by several applications of dilute lye and subsequent oxidation. Usually, three or more solutions of sodium hydroxide of decreasing concentration are applied. This gives the fruit a darker and more uniform colour and the compact texture is retained.

The procedure is carried out in a battery of concrete tanks of varying capacity, each of which is connected to four pipes supplying water, lye, brine and compressed air. There is also a drainage system for the discharge of the spent lye, the washing water and the brine.

The various steps involved in the process are as follows:

a) Immersion of olives in the first batch of lye

The first lye solution is the most dense and usually contains 1-1.5% sodium hydroxide, depending on the fruit variety, its ripeness and the temperature prevailing in the factory throughout the process. The olives remain in the first bath until the alkali penetrates the skin. The lye is then removed and the olives remain dry inside the tank in order for the polyphenols to undergo oxidation. To obtain a uniform colour, the olives have to be stirred 3-4 times every 24 hours. This is done by introducing water into the tank followed by compressed air for 2-3 minutes. The water is then drained off and the olives allowed to dry. If compressed air is not available, then the olives are stirred with a wooden paddle. If this is not done, the colour where the olives touch remains lighter than the rest of the epidermis.

Exposure to air after the first lye treatment generally lasts 3-12 hours or until the epidermis acquires a uniform black colour. In some factories, the olives are covered with water and compressed air is injected continuously. This gives a more uniform but less intense colour. The darkening of the epidermis with the first application of lye is the most critical step of the whole process. Each factory seems to have its favourite way of darkening the olive skin.

b) Successive lye applications

After the first lye bath, the olives are submerged in 3 or more lye solutions that progressively penetrate further into the flesh with the last solution reaching as far as the stone.

The lye concentration in the successive baths may be the same (0.5%) or may decrease progressively from 1.5% to 1%, 0.75% and finally 0.5%. Immersion lasts from 2 to 24 hours depending on the lye concentration and is followed by exposure to air from 4-18 hours each time. The total duration of the darkening process in the Californian industry is 5-6 days with the maximum being 9 days.

c) Remaining procedures

After the darkening process, the olives are washed in water for 5-7 days with the water being changed at least twice a day to remove the residual lye. In most plants the water is heated to 80ºC (175ºF) by blowing heated steam into it. This prevents the softening of the flesh and fish-eye deterioration. The washed olives are then submerged in a dilute brine (3-4% salt) and left for up to one week. Some factories use a more concentrated brine during the curing phase followed by a more dilute brine in the cans so that the final salt content of the brine is 3%.

Sorting and size-grading are repeated after brining because the process sometimes causes weight loss and the olives are sorted according to their colour – black, light brown and dark brown.

The olives are then canned and the cans are filled with brine with a salt content of 2.5-3.5%. They are then exhausted by heating when full of olives and brine for 4-5 minutes at 93.3-100ºC (200-212ºF) or are filled with boiling-hot brine. During this process the temperature in the centre of the can must reach 85ºC.

If the olives are packed in glass jars, during the heat treatment air pressure of 15-20 lbs must be attained in the autoclave to keep their lids on.

After exhaustion, both cans and jars are submitted to heat treatment at 115.5ºC (240ºF) for approximately 1 hour, depending on the size of the containers.

After sterilisation the cans are cooled under running water.

PREPARATION OF TREATED BLACK OLIVES IN ALGERIA

Algeria is one of the three main olive-producing countries that specialises in the processing of treated black olives[5,6].

French technology is applied and the resulting olives differ from those produced elsewhere in that they conserve the taste and aroma of the fruit because the lye treatment is discontinued before all the flesh is affected.

Treated black olives are the most predominant of the trade preparations of the approximately 6,000 tonnes of table olives produced in Algeria. The table olive industry is located in the northern part of the country around the city of Oran and the bulk of processing takes place in ten cooperative factories in the towns of Sig, Mohamedia, Sidi Bel Abes, Ain Temuchen, Saida, Mascara, Tighenif, Relizane, Djidiouia and Tlemcen.

The main variety used for processing as table olives is the dual-purpose Sigoise variety, followed by the Spanish Sevillana and Gordal varieties that have been acclimatised to the regions of Relizane, Djidiouia and Mascara.

Flow sheet for treated black olives in Algeria

The three main differences between Algerian treated black olives and those produced in other countries are:

- olives of the Sigoise variety are used when completely ripe and not when semi-ripe;
- the olives are exposed to air by placing them in plastic crates and not by injecting compressed air into the tanks of olives covered with water or brine;
- the ring of flesh that is left untreated around the stone after the lye treatment gives the Algerian olives more taste and aroma and makes them slightly bitter.

The processing stages are as follows:

Harvesting
↓
Storage in brine
↓
Exposure to air
↓
First application of lye solution
↓
Oxidation by exposing the olives to air
↓
Second application of lye solution
↓
Oxidation by exposing the olives to air
↓
Washing by immersion in dilute brine
↓
Sorting and size-grading
↓
Packing in barrels topped up with new 10 Bé brine
↓
Immediate distribution to the markets

Processing

The fruit of the Sigoise variety is harvested when completely ripe. Its flesh is compact and is jet black in colour. Its size is medium to small and the stone is relatively big so the flesh-to-stone ratio is only just acceptable for table use (around 5:1). It is picked manually and beating the trees with stakes is prohibited by law.

Only a small percentage of the harvested olives are given the lye treatment straight away. The rest is stored in underground tanks shaped like ancient Greek amphoras that hold about 35 tonnes of olives and are about 4 m deep. These amphoras were built and used to store wine during the period of French colonisation.

The olives are covered with 10 Bé brine initially but salt content drops to 6 to 6.5% when equilibrium is reached. In the past, unloading the olives from the amphoras was a difficult, time-consuming and expensive task but this problem has now been solved with the use of absorption pumps. Sigoise olives are very resistant and suffer only when the amphoras remain semi-full of olives for an extended period of time. In this case oxidative microbes grow on the surface and form a thick and slimy membrane. Under such conditions softening and *zapateria* are likely to occur.

When required the olives are removed from the amphoras, placed in plastic crates and left to drain exposed to the air. They are then submerged in the first lye bath with a density of 2-3 Bé. In some factories, the olives remain in the lye until it penetrates the skin and impregnates 1/2 or 2/3 of the flesh and they are then washed in running water and exposed to the air. This is not to be recommended because the darkening of the fruit is the result of its polyphenols being oxidised in an alkaline environment and washing adversely affects the whole procedure. The air exposure that follows lasts for 2-3 days and the olives are then immersed in a dilute brine (3-4 Bé) for 12 hours to remove just the residual lye on the outside surface of the olives.

Sorting and size-grading of olive fruits is usually done before immersion in the first lye solution. Exceptionally, the olives may be darkened straight from the orchard in which case they are sorted and size-graded before being placed in the barrels. In certain factories sorting is carried out at the end of processing, whether or not it has been done previously. The whole process ends with packing in barrels holding from 170 to 190 Kg of olives that are filled up with 10 Bé brine.

Comments on the Algerian method of preparation and distribution

The washing of lye-treated black olives in Algeria is very mild consisting in submersion in dilute brine (3-4 Bé) for a few hours. The olives are then barreled and covered with 10 Bé brine. Under the above conditions, the flesh retains enough alkali that is partly transferred to the brine when the equilibrium is set. In this way the pH value is alkaline. At the bottom of the barrels, the anaerobic conditions may lead to the development of the toxin-producing bacterium *Clostridium botulinum* when the salt content of the brine is below 6-6.5%.

The fact that serious outbreaks of food poisoning due to botulism have not been reported is either pure chance or because this bacterium is rare in the Mediterranean area.

When packed in barrels this trade preparation is sensitive to the foul-smelling deterioration known as *zapatería*. Most of the Algerian olives are exported to France where they are repacked for the retail market in cans filled with fresh brine and sterilised at a temperature of 121°C for a variable length of time, depending on the size of the containers.

Acidification of the brine with lactic acid to a pH of 3.5 and subsequent thermal treatment at 100°C which is the practice in some canneries in the Oran region does not guarantee the sterilisation of the product. The flesh is alkaline and when equilibrium is reached, the alkali released into the brine increases its pH value so that *Clostridia*, whether toxin-secreting or not, are not killed by the heat treatment. They can then grow in the cans and spoil the contents by forming toxins in the form of gas or acids.

PREPARATION OF TREATED BLACK OLIVES IN SPAIN

In recent years, Spain has taken increasing interest in the production of treated black olives[24, 27, 30]. Since its entry into the EEC, the large industrial units producing table olives in Spain have passed into the hands of multinational companies controlled by American capital which obviously were keen to prepare treated black olives for export to the US. Twelve plants now produce this trade preparation in Spain, of which four are of large capacity.

In collaboration with the researchers of the Institute for Fats and Oils of Seville (Instituto de la grasa y sus derivados) these plants have developed a slightly different production technique from those used in California and Algeria. In general, the olives produced in Spain have a better colour and texture than similar olives from California and Algeria but their organoleptic characteristics are slightly inferior.

The production of treated black olives requires a complete processing line for the darkening and canning processes which obviously involves high levels of investment.

The most serious problem faced by the Spanish researchers was gas-pocket formation (fish-eye) during the storage of the olives in the polyester tanks.

Flow sheet for the production of treated black olives in Spain

Harvesting
↓
Transport
↓

↓
Preservation in brine
↓
Lye treatments – Oxidation
↓
Washing
↓
Immersion in ferrous gluconate (ferrous lactate) solution
Pasteurisation
↓
Sorting and size-grading
↓
Packing in lacquered cans or glass jars
↓
Sterilisation (thermal treatment)
↓
Marketing

Harvesting

The varieties used in Spain for the production of treated black olives are Hojiblanca, Cacereña and Sevillana. Of the three, the most important is Hojiblanca. Its small fruit (280-300 per kg), previously used only for oil production, is compact and rich in polyphenols and fibres. Hojiblanca olives are only rarely subjected to lactic acid fermentation as this tends to give them a woody texture whereas they are ideal as the raw material for treated black olives.

Cacereña is quite probably a clone of Manzanilla. It is grown in Extremadura where lactic acid fermentation is not widely practised because of the predominating low temperatures.

The Sevillana variety is used only when large-sized treated black olives are required.

The fruit is harvested manually when a straw yellow colour, generally before it begins to turn red.

Sorting and size-grading

Both processes are performed either at the beginning or the end of the darkening process. In the first case, the dark green olives are set aside and subjected to lactic acid fermentation, the riper olives are darkened and the completely ripe ones are sent to the oil mills. Size-grading is recommended because the colour obtained per batch is more uniform.

Initial preservation in brine

If the olives are darkened as soon as they come from the orchards, the end product retains a slight fruity taste that is considered a defect for this trade preparation as the end product is expected to have no taste or aroma, only a very compact texture and a deep and uniform black colour. Exceptionally, they may have a slight aroma of fresh straw. It is commonly believed that olives intended for darkening by oxidation have to be stored for 2-6 months in order to give a final product of good colour and compact texture. During the storage period, the olives are submerged in brine of varying salt content.

When the technique of darkening by oxidation was first applied, the olives stored in brine showed serious deterioration such as fish-eye, butyric fermentation, *zapateria*, etc. These abnormalities were due to the activity of the mixed microflora comprising yeasts, gram negative bacteria and lactic acid bacteria. The latter participated only exceptionally in spite of the fact that anaerobiosis inside the tanks was almost complete.

The most serious olive deterioration during the storage stage was gas pocket formation, also known as fish-eye and *alambrado*. It was eventually established that the main causative agents were the two yeast species, i.e. *Saccharomyces oleaginosus* and *Hansenula anomala*[19, 27].

The deterioration was initiated by the release of large amounts of carbon dioxide and/or hydrogen causing fissures in the flesh and blisters under the epidermis.

The problem is solved by inhibiting microbial growth by acidifying the covering brine with acetic acid and passing a current of air through the product to create an aerobic environment throughout the fruit load. Optimum air dosage was found to be 0.2-0.3 litres per hour and per litre. Air injection can be either continuous or intermittent, in which case it is carried out every other day or for only eight hours a day. The air passes from a compressor through pipes leading to various tanks simultaneously, each with a reducing valve to keep pressure stable. The air is fed into the lower end of the aeration column at the centre of each storage globe. There are also 225 holes in the walls of the column to allow brine to enter. The recommended duration of aeration is 30-45 days. The salt content of the brine is maintained at 6% with the addition of solid salt but in early spring is raised to 8% or 8.5% if the olives are to remain in the brine during the summer months.

The pH is made to drop by adding acetic acid to the brine. There is no buffer capacity because of the complete absence of sodium hydroxide.

The selective growth of lactic acid bacteria in the brine of Hojiblanca and Sevillana olives but not in the brine of Lechin and Verdial olives indicates, according to the Spanish bibliography, that the growth of this type of bacteria depends on the phenols present in the olive flesh and this varies greatly from one variety to another.

Darkening by oxidation

The processes of removing the bitterness and darkening are accomplished by immersing the olive fruits in three successive alkali solutions and exposing them to the air between each immersion. The procedure is as follows[30]:

a) First immersion

The alkali concentration of the first solution is 1.5-2% or up to 3%, depending on the environmental temperature, the ripeness of the fruit and the duration of storage in the brine.

Treatment is in concrete or stainless steel tanks with a conical base. Immersion lasts 1.5-2 hours, long enough for the alkali to penetrate the epidermis. Aeration is carried out only occasionally but only to stir the fruits, not to oxidise them.

b) Washing and aeration

When the fruits have been in the lye long enough for it to penetrate the skin, the solution is replaced with water into which air under pressure is introduced for about twenty hours. This process oxidises the phenols in the flesh which enter the alkaline solution.

c) Second immersion

The initial alkaline solution is re-used for the second immersion which lasts until the alkali has penetrated one millimetre of the flesh. Aeration is applied as above only to ensure uniform treatment of all the fruit.

d) Washing and aeration

The alkaline solution is again replaced with water and air is injected into the tanks. This process also lasts about 20 hours.

e) Third immersion

The solution from the second immersion is re-used after strengthening with 1-1.5% soda. The olives are left in this solution until the alkali has penetrated all the flesh and reaches the stone (about 4-6 hours).

f) Washing and aeration

The last washing and continuous aeration process lasts for 1, 2 or 3 days. This is the most important stage of the whole process during which the pH drops from 11 to 9 as a result of both the washing and the addition of hydrochloric acid. The amount of foam formed is also reduced. In some industries, 1-2% salt is dissolved in the water of the last wash to keep the fruit floating during oxidation.

g) Immersion in ferrous gluconate or ferrous lactate solution followed by immersion in dilute brine[30].

After oxidation and washing, the fruits are immersed for 24 hours in a ferrous gluconate solution (0.8-1‰) or a ferrous lactate solution (0.5-0.6‰). In both cases, the tannins react with the iron and produce iron tannate, a dark-coloured compound, which improves the colour of the fruit.

The olives are then washed with water and immersed in dilute brine at 3-4 Bé for 2-3 days during which time they absorb salt until equilibrium is reached between the brine and the fruit flesh. To prevent deterioration, steam is injected into the olive load until the temperature rises to 90-95ºC.

h) Sorting and size-grading

Sorting is compulsory whereas size-grading is only carried out if the olives were not previously graded on arrival from the orchard.

i) Packing

The olives are packed into lacquered cans holding between 0.5 and 5Kg of olives. The filling brine contains 3% salt and in some cases 1‰ citric acid. 0.2‰ of ferrous lactate is also added to protect the colour. Tolerance to iron differs from one country to another and this has to be taken into account during the canning process[33,40].

j) Thermal treatment

This has to be severe enough to completely sterilise the product and leave sufficient safety margins. This type of olive is slightly acid (pH 5.5-4.0) and contains up to 3% salt so preservation is based exclusively on the thermal treatment. If not properly sterilised, the anaerobic conditions inside the cans can lead to the growth of *Clostridium botulinum* which not only spoils the product but may cause severe types of food poisoning (botulism).

The olives may be packed in glass jars but in the autoclave extra pressure will have to be applied in order to keep the lids of the jars in position.

In addition to whole olives darkened by oxidation, the table olive industry also produces pitted olives, rings of olive flesh, olive paste, etc.

To fill the cans, boiling brine is used so that the temperature in the centre of the can reaches 71º or more. Generally, however, thermal treatment is at 115-116ºC (240ºF) or 121.1ºC (250ºF). In general, the lower the temperature of processing, the longer the time of the thermal treatment. The National Canners Association of the USA recommends the following parameters for thermal processing of treated black olives:

- at 115°C (240°F), 60 minutes
- at 121.1°C (250°F), 50 minutes when the capacity of the can is no more than 3 Kg.

The Instituto de la Grasa y sus derivados in Seville, Spain recommends the following parameters for the thermal processing of treated black olives:

Can capacity	Thermal treatment	
	Temperature °C	Time (minutes)
1 kg or less	115-116 °C	60
3 kg or less	115-116 °C	70
1 kg or less	121.1 °C	45
3 kg or less	121.1 °C	50

Conclusions on the preparation and marketing of olives darkened by oxidation

Olives darkened by oxidation are the trade preparation of the future. This is not a harmful product for the human organism because the sodium hydroxide used is also used in the processing of other foods. Any remaining lye is neutralised by the high buffer capacity of the flesh while residual sodium is a normal ingredient in foods and completely necessary for the human body. Rumours that olives treated with alkali are harmful and cancerigenous have proved to be unfounded.

Residual traces of NaOH in olives are tolerable but any excess is not acceptable to consumers who dislike the soapy taste.

In Greece when the law is changed and the processing of olives darkened by oxidation is permitted, as well as in other countries producing this trade preparation, it must be understood that the process is a complex one and that proper thermal treatment is essential if the product is to be completely safe for consumers.

Licences for the production of olives darkened by oxidation should only be provided where complete processing and canning lines are available and where food technologists are employed to control the process.

OTHER TYPES OF TABLE OLIVE OF SECONDARY ECONOMIC IMPORTANCE

INTRODUCTION

In addition to the three trade preparations of table olives, the main olive-producing countries produce a variety of other types of table olive but in smaller quantities. Taken separately, these are of secondary importance but together they make up a considerable proportion of olive production – from 1986-87 to 1991-92 they accounted for 20-22% of total world production.

The following are a selection of these minor types:

- Green ripe California-style olives
- Sweetened or semi-fermented green olives
- Castelvetrano-style green olives
- Untreated Sicilian-style green olives in brine
- Untreated bruised green olives
- Untreated olives turning colour in brine
- Untreated split black Kalamata olives
- Untreated, naturally-shrivelled black Thruba olives
- Untreated black olives in dry salt ('date' olives)
- Black Greek-style olives
- Olives of various types produced in Italy
  - Treated dehydrated olives turning colour
  - Untreated dehydrated black 'Maiatica di Ferrandina' olives
  - Olive paste
  - Untreated 'Itrana' olives
- Various commercial types of table olive from the United States, Morocco, Syria and Argentina

GREEN RIPE CALIFORNIA-STYLE OLIVES

This type of table olive is prepared from Mission and Manzanilla varieties when dark green or starting to turn red.

Submerge in three alkali solutions containing 1.5-1.64%, 0.75% and 0.5% NaOH respectively keeping the olives in water while changing the solution to avoid air oxidation.

Wash off the residual lye submerging the olives in water changed 2-3 times a day for about one week.

Cure the washed olives in dilute brine at 3-4 Bé for 2-3 days.

Pack the olives into lacquered cans of varying capacity but never more than 3Kg. Fill with boiling brine containing 2-3% salt. Seal and heat to 115.5°C (240°F) or to 121.1°C (250°F) for 50-60 minutes depending on the size of the containers.

These olives have a neutral flavour and are appreciated only by North American consumers.

SWEETENED OR SEMI-FERMENTED GREEN OLIVES

Treat dark green Konservolia olives in the same manner as those intended for lactic acid fermentation. Allow soda to impregnate 3/4 or all of the flesh then wash.

Submerge the olives in brine at 8-10 Bé and leave for about 10 days.

Replace the mature brine with fresh brine acidified with 0.4% lactic acid (400 mg of lactic acid per 100 cc of brine).

Pack olives into plastic barrels closed with screw covers but not in hermetically closed cans that are likely to swell if any gas is released.

Loosen the screw covers from time to time to allow the CO_2 to escape.

Greek production of these olives is usually exported to Naples (Italy) where they are consumed unfermented (sweet) or slightly fermented. If not consumed rapidly, this type of olive deteriorates or undergoes lactic acid fermentation and then is not sweet but sour in taste.

CASTELVETRANO-STYLE GREEN OLIVES

This type of table olive is produced exclusively in western Sicily (Castelvetrano, Trapani and Campobello) from raw olives of the 'Nocellara di Belice' variety. Yearly production is estimated at 12,000-15,000 tonnes.

a) In Sicily the olives are harvested at the green stage, then are sorted and size-graded. They are then washed with water under pressure.

Pack into plastic barrels holding 150 Kg and fill with 90 l of sodium hydroxide solution at a density of 3.5-3.7 Bé. Dissolve 5 Kg of salt into each barrel.

This type of product is consumed mainly in Naples (Italy) before the flesh and brine reach equilibrium. It is generally sold outdoors from bowls of water at football matches, in cinema queues, etc. Genuine Castelvetrano-style olives contain 2.25% salt, have not undergone lactic acid fermentation and are sweet.

b) Greece exports to Italy 2,500 tonnes per year of Castelvetrano-style olives for which the Konservolia variety is used.

After washing, the olives are packed in plastic recipients holding between 13 and 50 Kgs of olives.

These are then filled with brine containing 2.5% NaOH and 8% salt. The soda content drops to 0.5% within 5-6 days and to zero (neutralisation) within 30-40 days after the start of processing.

At equilibrium Castelvetrano olives of Greek origin contain 4.5% salt, that is, double that of the authentic olives prepared in Sicily.

Greece exports these olives to Italy under the responsibility of the Italian importer because this product is not considered fit for consumption and is not permitted in Greece.

To prepare safe Castelvetrano-style olives, the salt content of the brine should not drop below 6% and 15 Kg of glucose syrup can be added per tonne of olives. Under these conditions the olives will ferment and the end product will be excellent because it retains all the taste and aroma of raw olives. However, they are sour rather than sweet as proper Castelvetrano-style olives should be.

Alternatively, a lye of 1.5-2% sodium hydroxide can be used inoculated with pure cultures of lactic acid bacteria. The pH of Castelvetrano-style olives is neutral or slightly alkaline and they contain less than 6% salt. Under the practically anaerobic conditions existing at the bottom of the containers, the toxin producing *Clostridium botulinum* can grow, giving rise to serious food poisoning. This type of olive is not produced in compliance with international regulations, EEC directives and the instructions of the International Olive Oil Council (IOOC). It is therefore expected to be prohibited in the near future.

UNTREATED SICILIAN-STYLE GREEN OLIVES IN BRINE

To prepare this type of table olive, harvest the olives when green, pack after sorting and size-grading into tanks and fill these with 8-10 Bé brine.

Anaerobiosis causes weak lactic acid fermentation due to the low buffer capacity of the brine (it contains no NaOH).

Allow to ferment for 7-8 months. Then remove the olives, pack into plastic barrels and fill up with fresh brine to be sent to the market.

However, this type of preparation gives rise to many technical and economic problems. The tendency of natural green olives to shrivel means that the salt content of the brine must be carefully adjusted. Equilibrium between the olive flesh and the brine takes place slowly, firstly through osmosis and then through diffusion, altogether taking about 50 days. These olives are bitter after processing and the length of processing makes production costly because it keeps funds tied up for 7-8 months.

An alternative is to pass the processed green olives (after approximately 50 days in brine) through a bruising machine and then sell as 'bruised green olives in brine'. These olives will be of good quality because the phenoloxidase enzymes will have been inactivated and the crushing marks will not therefore turn dirty black which is the case with genuine bruised olives.

UNTREATED BRUISED GREEN OLIVES

Any type of olive can be used for this type of preparation, even those that are speckled with the infertile pricks of the Dacus fly.

Wash thoroughly, sort and size grade and then make two lengthwise cuts opposite each other.

Crush the flesh by passing the incised olives through a bruising machine so that the stone remains intact.

Place the bruised olives in wooden containers or tanks made of cement and cover with 10 Bé brine for anaerobiosis.

When the weak lactic acid fermentation is over, take the olives out of the tanks, pack into cans, fill with the 'mother' brine and send to the market.

To speed up the operation, the bruised olives can be immersed in water for 10-12 days, changing the water once every 1-3 days according to local customs. In this way the olives rapidly lose their bitterness and can be sent to the market earlier.

Add aromatic and savoury flavourings (oregano, fennel, coriander, slices of lemon, hot pepper, etc.) according to consumer preference.

If semi-fermented Spanish-style green olives or untreated green olives in brine are used following the same procedure, the end product is of better quality.

The custom in Algeria is to add 200 grams of crushed bay leaves to barrels containing 170-190 Kgs of olives filled up with 8 Bé brine.

This type of olive is produced in small or moderate quantities in all olive-producing countries and, although they do not look good, they are highly prized in the local markets. They are practically always consumed within the country of origin with some being exported to Italy, the USA, Canada, Germany and Arab countries. The main producing countries are: Greece (2,000-2,500 tonnes), Italy (1,600 tonnes), Syria (1,000-1,500 tonnes) and Algeria (500 tonnes).

UNTREATED OLIVES TURNING COLOUR IN BRINE

These are prepared in the same way as ripe olives in brine and have the same characteristics except for their colour. This is actually a by-product of the production of natural black olives and is generally offered at a lower price on the market.

In Greece the olives are chiefly from the Konservolia and Chalkidiki varieties. Yearly production is estimated at 3,000 - 5,000 tonnes and small quantities of this type are also produced in Italy, Yugoslavia, Cyprus, Turkey, Syria and Egypt.

UNTREATED SPLIT BLACK KALAMATA OLIVES IN VINEGAR[54]

Split black Kalamata olives in vinegar are a trade preparation of particular interest for Greece[64]. They are made from Nychati or Kalamata olives. Each olive has two lengthwise incisions, one on each side, and they are preserved in brine acidified with top-quality wine vinegar (3-4 parts of brine to 1 part of vinegar). Kalamata olives are grown only in certain regions of Greece (Laconia, Messinia, Aetolico) and annual production reaches 8,000 to 10,000 tonnnes. The olives have certain outstanding characteristics – they are a deep black colour, the flesh is rich in fermentable substances and has a fair oil content, the skin is thin, elastic and resistant. Data concerning fruit size, the flesh-to-stone ratio, etc. are given under Table olive varieties worldwide (p 300).

Split black Kalamata olives are not fermented – they are merely preserved by the vinegar and salt through anaerobiosis.

Flow sheet for the preparation of split black olives in brine mixed with vinegar

Immediate preparation
↓
Sorting
↓
Splitting
↓
Immersion in water for 7 days changing water daily
↓
Packing in cans
↓
Filling with brine acidified with vinegar (3 parts brine 10-11 Bé, 1 part wine vinegar)
↓
Marketing
↓
Storage in tanks in water without anaerobiosis
↓
Removal, sorting, size-grading
↓
Return to tanks with 6 Bé brine, partial anaerobiosis
↓
Removal, exposure to air for oxidation.
↓
Splitting
↓
Packing in cans (1,2 and 13 Kg)
↓
Filling with brine acidified with vinegar (3 parts 10-11 Bé brine, 1 part wine vinegar)
↓
Marketing

The olives are harvested manually when completely mature but not overripe. They should be jet black with dark red, compact flesh. On arrival at the factory, they are placed in tanks and covered with water for 2-3 months. Anaerobiosis does not take place and oxidative microbes grow on the surface, forming a leathery membrane. The olives absorb water and gain in weight.

After approximately 3 months, the olives are removed, sorted and size-graded. They are then returned to the tanks, covered with 6 Bé brine (6% salt) and a heavy slatted cover is placed on top of them. In this way, the olives are kept permanently submerged. The anaerobiosis is partial because the brine flows over the cover and helps the leathery membrane to form. The salt content of the brine is raised to 8% during the spring and to 8.5% if the olives have to remain in storage over the summer. They must be prevented from shrivelling.

When required, remove the olives from the tanks, expose them to air to oxidise for 24-48 hours, sort once again and pass them through the splitting machine which makes one lengthwise incision on each side. Pack in cans and fill with a mixture of brine at 10-11 Bé and vinegar in a proportion of 3-4:1 (75-80 Kg of brine: 20-25 Kg of vinegar). The amount of brine required is 60-70% of the olive weight so a rectangular can containing 13 Kg of drained olives also requires 6-7 Kg of brine, 1.4-1.5 Kg of vinegar and 50-60 g of good quality olive or seed oil. Small cans (1-2 Kg of olives) should be closed hermetically and large containers (13 Kg) with stoppers.

Research in Greece has found that, during the 2-3 months storage in water, Kalamata olives undergo typical lactic acid fermentation during which approximately 1% lactic acid is formed thus preventing spoilage. Nevertheless, storing olives in water is risky and in certain cases they end up smelling of mud.

Olives that have been kept during the summer in brine with 8.5% salt have to be covered with more dilute brine when packed in order to prevent them from being too salty.

Before packing for the retail market, Kalamata olives have to remain in the tanks until all fermentation subsides and the brine becomes clear. If it remains cloudy, the olives have to be pasteurized or secondary fermentation will take place and the cans will swell. Bulging cans of olives are considered unfit for consumption and potentially dangerous. It is obligatory for closed cans of olives to undergo heat treatment.

Packed Kalamata olives are at their best when the brine contains a maximum of 7% salt and 1.25% acidity expressed as lactic acid or 0.83% expressed as acetic acid. The most serious drawback with Kalamata olives is that the colour leaches out into the three different solutions in which they are stored (first water, then brine, then the acidified brine). The colour could be improved if the olives were stored directly in brine and the same brine were used in filling the retail packages but, in this case, the 'mother' brine would have to be completely sound and clear.

Swelling, particularly in the small cans, can be limited by leaving sufficient vacuum in the cans, by ensuring that fermentation is complete before packing and by pasteurising the cans at 70ºC for 20 minutes (cans containing 1 Kg or less) and for 30-35 minutes for large size cans (containing a maximum of 2-3 Kg).

Although the initial immersion of olives in water is risky, it improves quality because the fact that part of the sugars are fermented means that acidity is reduced and the colour improves. At the same time, the phenoloxidase enzymes are inactivated so that, when the olives are split, the cuts do not turn a dirty black colour. If the traditional method is followed and the olives are stored in water for 2-3 months, solid salt can then be dissolved in the water, if it is in good condition, and it is thus turned into storage brine. In this way, the loss of anthocyanins through leaching is much less marked.

Raw Kalamata olives can be submerged in brine containing 8-10% salt which then stabilises at 6% or less. By the end of the storage period, these olives have lost enough of their bitterness and can be packed directly (without incision), topped up with mature brine (either genuine or diluted) or with a mixture of fresh brine and vinegar in a proportion of 3/4:1. The cans are then given a thermal treatment.

These olives have excellent organoleptic qualities, particularly when the salt content after reaching equilibrium is 4% or less. In general, raw Kalamata olives are rich in both colouring substances and fermentable matter so they ferment readily when submerged in water or brine containing up to 8% salt. In addition, the polyphenol content of the flesh is not high enough to inhibit the growth of lactic acid bacteria[67].

A method used in Greece to speed up preparation is to pass the completely ripe olives through the incising machine, then immerse them in plain water, changing it once a day for a week. This sweetens the olives. The rest of the process is the same as above and in this way the product will be ready for consumption within 30 days from harvest. They thus retain most of the taste and aroma of the fruit but have the drawback that the incisions gain a dirty black colour as a result of the activity of the phenoloxidase.

A method used in Algeria to prepare imitation Kalamata olives is as follows. Sigoise olives of any colour are sorted and size-graded, then split as above. They are then packed into barrels holding 160-190 Kg of fruit which are filled with brine at 7-9 Bé. When the first batch has been removed, the olives are again sorted and size-graded. To each barrel is added 3 Kg of good quality vinegar, 250 g of olive oil, 100 g of citric acid and 250 g of dried, powdered bay leaves. The olives are then covered with fresh brine with a 9% salt content.

UNTREATED BLACK THROUBA-STYLE OLIVES

a) Black Throuba-style olives are prepared exclusively from the Thrubolea variety (Olea europaea var. media oblunga) grown in Crete, the Aegean islands, Attica, Boeotia, etc. Throuba olives lose their bitterness on the tree automatically, provided climatic conditions are right. This is a characteristic not found in other olive varieties. It is claimed in ancient Greek literature that this loss of bitterness is due to the activity of an enzyme coming from the fungus *Phoma oleae* that grows on the skin of olive fruits. This has not, however, been substantiated by research and recently it has been reported that the fungus growing on Thruba olives is *Alternaria*. The issue is not yet clear and requires further research. It is also claimed in the literature (Balatsouras, 1980) that the first olives used as food might have been the Throuba olives since they sweeten on the tree without it being necessary to process them to remove the oleuropein. Throuba olives quite possibly motivated the ancient peoples of Attica (around Athens) to proceed further and produce artificially sweetened olives, the 'dry-salted' olives using the Megaritiki variety. The technique of using solid salt to debitter olives seems to have been used by all the Mediterranean peoples and the 'dry-salted' olives produced were always known as 'Greek-style olives' or 'olives à la façon grecque'. This term has been retained in spite of the fact that these olives have little significance and are not the main representatives of the Greek table olive industry.

b) To prepare Throuba olives, proceed as follows.

Leave the olives on the tree until they lose their bitterness. Then harvest both those on the tree and those that have fallen to the ground. Place in baskets, wash thoroughly in water under pressure and spread outdoors to drain. Pack dry in plastic sachets or other containers under a vacuum. Add small quantities of solid salt not to preserve the product but to improve the quality. Alternatively pack into containers filled with good quality olive oil without salt. This type of product is generally consumed by people suffering from heart and kidney disorders.

UNTREATED BLACK OLIVES IN DRY SALT ('DATE' OLIVES)

Dry-salted or 'date' olives have their bitterness removed with solid salt that squeezes out of the fruit flesh the vegetable water with most of the oleuropein. They end up shrivelled and decidedly salty, containing more than 10% salt. They are also partially dehydrated and contain 27.5% moisture, that is, half the original amount. They contain practically all the original fermentable matter, a higher proportion of fatty substances than the raw material owing to the loss of water-soluble substances (39.074% as against 26.27%) and more protein content at the final stage (2.906% as against 1.802%). They have very low acidity and the pH of the final product is practically the same as that of raw olives indicating that no lactic acid fermentation takes place[59].

Dry-salted olives have a good black colour, a higher calorie value than all other trade preparations of table olive, are neutral or slightly acid and shrivelled. They are packed dry (without brine) and are very salty. Consumer demand for such olives is on the increase because, being dry, they are preferred for picnics, excursions, ceremonies, etc.

To prepare 'date' olives[57], use completely ripe or even over-ripe olives of the Thassitiki variety cultivated in northern Greece or Megaritici cultivated in Attica, Megara, Voiotia and elsewhere. In other olive-producing countries, ripe fruit from table or dual-purpose varieties can be used.

The fruit is transported to the processing plants in plastic boxes. It is sorted and size-graded and then packed into concrete tanks in layers alternating with solid salt. The salt content is estimated as 30% of the fruit weight and is so arranged as to leave a 2cm thick layer on top. This technique was possibly taken to Greece from Turkey by the refugees during the catastrophe of Asia Minor.

Although this is an enormous quantity of salt, it is insufficient to prevent the growth of moulds because it has been found that some moulds can grow in brine saturated in salt[52]. The quantity of salt can be reduced to 1/5 or even less if the olives are soaked in vegetable water saturated in salt. Such soaking should be done once a day using a portable pump. This is the technique applied by Algerian technicians in the preparation of Greek-style olives.

10-15 days after layering, reject part but not all of the vegetable water extracted from the olives through the leaching effect of the solid salt. If this is not done, the olives will be excessively salty and will end up too dry in the later spring-early summer period.

Remove the olives from the tanks after 30-40 days. During this period no fermentation takes place – only physical and chemical changes as well as loss of oleuropein. The olives are then left exposed to the air for oxidation to improve their colour. They are then sorted once more and packed dry in plastic containers or cans mixed with crushed rock salt. The latter can be omitted from cans because they are sealed under a vacuum.

Water activity in dry-salted olives is very low and impedes the growth of the majority of microbes although there are certain fungi that can grow on them. Thermal treatment cannot be used since there is no liquid phase in the sealed product. Dry-salted olives, whether heat treated or not, are never sterile. The excess salt affords a degree of protection to the product but this is insufficient. Better results might be obtained by sealing the contents under vacuum (all moulds require oxygen) and by adding certain fungal deterrents such as potassium sorbate.

The following method is suitable for processing on a domestic scale or in small-scale installations[59]. Completely ripe or even over-ripe olives of the Megaritiki variety are washed thoroughly with water under pressure then spread outdoors in the sun to drain. They are then packed into the same baskets that were used for harvesting, alternating the layers of olives and solid salt. They are left for 30-40 days and during this period the salt squeezes the vegetable water out of the flesh. This has to be collected in barrels or pits. The olives are then edible and are packed dry in paper, plastic boxes or small sachets. They are usually coated with grains of salt.

In spite of their high salt content, dry-salted olives do not keep well and quickly lose their moisture because of their salt coating. They should therefore be consumed quickly or else stored in containers holding a layer of vegetable water saturated in salt.

BLACK GREEK-STYLE OLIVES[5,6]

This commercial type of black olives, in spite of its name, is prepared exclusively in Algeria. Basically, the olives are soaked in the vegetable water that is extracted from them when layered with solid salt.

The vegetable water is saturated in salt and quite possibly in phenols. It is practically sterile as, according to the literature, it has been found to support the growth of only one species of yeast.

The olives should be of the Sigoise variety, completely ripe, dark black and with a compact texture. After picking by hand, they are sorted and size-graded then sent either direct for processing or stored underground for 2-6 months or even longer.

For processing, remove the olives from the stores, place in plastic boxes and leave to drain. Submerge them in an NaOH solution at 2.7-3 Bé for 9-10 hours or until the alkali penetrates the epidermis and imgregnates half or 2/3 of the flesh. Wash, although this is optional. Expose to air by placing in boxes and transferring from one box to another once a day for 3-4 days. Pack into wooden barrels in layers alternating with solid salt in a proportion of 160-170:9-10 (fruit to salt). Close the barrels making them watertight then place in a horizontal position. Roll the barrels once a day along 4-5 m, changing direction daily. This way the barrels complete three turns so that the olives are soaked with the vegetable water extracted by the leaching effect of the salt. The barrels need to be rolled for 30-45 days and during this time the olives lose their bitterness.

They are then removed from the barrels, placed in plastic boxes and exposed to air oxidation for 4-5 days. During this period they must be transferred daily to a different box.

They are then sorted again and packed into the same barrels. The vegetable water from each barrel (mature brine) is added (13-15 Kg) mixed with fresh brine at 12 Bé up to a total amount of 25 Kg.

These olives are generally exported to France, Rumania and Bulgaria but in the places of destination it is still necessary to continue rolling the barrels until the olives are finally sold to the customer. Grocers must take out just the quantity that they can expect to sell in a few days, leaving the rest in the barrels which they roll in order for the vegetable water to soak the olives and preserve them until they are finally consumed.

To prepare genuine Greek-style black olives, use raw olives of excellent quality and proceed as described above, omitting only the lye treatment.

Turn the barrels for 45-60 days. The removal of bitterness is based exclusively on the leaching effect of solid salt. Genuine Greek-style black olives are decidedly bitter but retain many of their fruity characteristics. Both artificial and genuine Greek-style black olives have a good taste (having less than 6% salt) and good eating qualities. Furthermore, the wrinkling is fine and well-formed so is considered a quality rather than a defect. This trade preparation is popular in many countries and it can be expected to gain in popularity in the future providing that processing is scientifically controlled so that the cost of industrial preparation is reduced. In this case, it could compete with other types of table olive on the international market.

TABLE OLIVE PRODUCTION IN ITALY

Italian production of table olives, which amounts to 80-100,000 tonnes and of which there are many different trade preparations of little economic importance, also includes many that are considered 'regional specialities'. These are becoming increasingly popular both within the European community and worldwide. This Section has already covered certain Italian table olive specialities such as Castelvetrano-style olives, Sicilian-style olives and bruised green olives.

However, there are other types of regional products that should be classified under 'specialities'. These are:

- Treated dehydrated olives turning colour
- Untreated dehydrated black Maiatica di Ferrandina olives
- Olive paté
- Untreated Itrana olives

The various methods of preparation are briefly described below.

Treated dehydrated olives turning colour

This type of preparation uses olives of various varieties of a large size and with a high flesh-to-stone ratio which are mostly imported untreated from Greece in barrels of brine. The olives are stored in barrels of brine at a concentration of approximately 8% for a period varying between 30 days and 10 months.

When ready the olives are removed from the barrels and placed in an alkaline solution (NaOH at about 2%) for 9-12 hours after which they are washed thoroughly in fresh water to remove most of the residual lye. Washing should be stopped when the flesh reaches a pH of 8.

The olives are then submerged in a 1.5-2% sulphur or iron gluconate solution for 12-18 hours. They are again washed, until the water is clear, to remove all the free iron. (Italian regulations stipulate that residual iron in the flesh must not exceed 300 mg/Kg whereas International Stardards limit iron residue to 150 mg/Kg).

At the end of the treatment with iron salts, which are used to stabilise the deep black colour, the olives are placed for about 12 hours in a 'flavouring' brine at a concentration that varies from region to region depending on local tastes (generally from 5 to 6% of NaCl).

The olives are then spread over plastic nets on frames or on wooden shelves and placed in a hot air oven at a temperature not exceeding 50ºC until the fruits are slightly wrinkled. At the end of the oven treatment, they are still a deep black colour and contain about 60% residual moisture. Recently in the Abruzzi microwave techniques have been introduced for this type of trade preparation. The olives are packed in wooden boxes holding 6-7 Kg and lined with food-grade paper which is often greased with olive oil. They are flavoured with orange peel and spicy pepper and sold loose. Under these conditions, the product is considered unstable from the food hygiene point of view because the flesh has a low saline concentration (± 2%) and a high pH value (7-8) so moulds and microbes develop rapidly.

Recently, processors of this type of trade preparation have started to pack the olives in heat-resistant, transparent plastic bowls or in glass containers which are then pasteurised.

This type of olive is mainly produced in Lazio (Castelmadama and other communes), in the Abruzzi and in Upper Molise and total production is estimated at approximately 10,000 tonnes. The products are sold throughout Italy and recently in certain countries of the EU, especially Germany.

Untreated dehydrated black Maiatica di Ferrandina olives

The *Maiatica di Ferrandina* variety is mostly grown in southern Italy, especially in Lucania, in the Matera province and in the Ferrandina commune. For this type of preparation, the olives are harvested when fully ripe. Their characteristics are:

- very soft and permeable skin
- good flesh-to-stone ratio (>5.5)
- easy to detach the flesh from the stone
- the flesh is black or pinkish throughout

Processing is as follows:

a) Washing of the fruit under pressure
b) Machine grading to divide the olives into two sizes
  - those with a diameter of under 16mm to be sent for crushing as they have 22% oil content and give top-quality oil
  - larger sized olives for processing as table olives
c) Removal of olives that are not completely black by an optical selector.
d) Scalding of olives in water at 90ºC for 1-3 minutes until, when rubbed between two fingers, the flesh can be felt to separate easily from the stone.
e) Salting. The olives are stored in open plastic containers layered between salt (10 Kg of salt for every 100 Kg of olives) for 2-3 days so that they can shed part of the vegetable water they contain.
f) Drying in a hot air oven at approximately 55ºC on frames covered with plastic nets in thin layers until residual moisture drops to 12-15%.

The fruit ends up black, very wrinkled, dry and slightly bitter but it has excellent organoleptic characteristics. This product has a low moisture level, is very nutritive and has good keeping qualities. It is sold in plastic sachets, small boxes or cartons mostly in Naples for rapid consumption. Production is barely over 3,000 q per year.

Untreated black olives in brine for the production of olive paté

The demand for black olive paté is on the increase. Olives of several varieties are used: *Leccino* from many regions of central and southern Italy, *Taggiasca* from Liguria and *Provenzale* from Puglia.

The olives are picked when fully mature and are processed in brine. After twelve months of preservation, when fermentation is complete (alcoholic and/or partly lactic fermentation), when the pH is below 4.5 and the salt concentration is between 7 and 8%, the olives pass into an special machine to separate the flesh from the stones.

This comprises a hopper attached to a horizontal stainless steel cylinder with 2-3 mm holes through which the olives are carried slowly by a screw that presses them against the walls of the cylinder so that just the pulp comes through the holes, with the stones remaining in the cylinder and the skins being expelled at the end of the run.

The paste is left to drain so that the vegetable water can run off. Extra virgin olive oil obtained from the same variety is added amounting to 5-10% of the weight of the paste and essential oils from natural aromas are added, such as thyme, laurel, rosemary, etc.

The paste is packed into small glass containers holding a maximum of 400 g. The product is used for spreading on bread as a snack or to condiment pasta (spaghetti, etc.) fish or meat, but always in small quantities both because of its intense flavour and its high cost.

The same procedure is adopted for the production of green olive paté in which lactic-fermentation, Spanish-style olives are used. There is not much demand for this product within Italy but it is fairly popular in the United States.

Even though the olive paté is fairly stable as long as it is kept in a cool place with its surface always covered with oil, it is advisable to pasteurise the containers and/or to add suitable anti-microbial preservatives (benzoic or sorbic acid).

Untreated black Itrana olives in brine

This trade preparation is produced only in Lazio where the Itrana variety is grown. This is a fairly vigorous variety giving medium-sized, dual-purpose fruit that is slightly ellipsoidal and often asymmetrical with a subconical apex. Being self-sterile, the Leccino variety is used to pollinate it.

The fruits are collected between February and March because only olives collected late keep the dark colour of the flesh after the fermentation process. So while this is a much-appreciated and well-priced product, it must be taken into account that those olives dropping off the tree are lost and there is inevitable alternate bearing as the tree is practically unproductive during the year of harvest. It is estimated that on average only 40% of the yield actually reaches sufficient maturity to be used in this way.

The olives are size-graded and those with a diameter of below 17 mm are sent for crushing. Their oil is 22-28% which can probably be attributed to the reduction in moisture in the pulp because of their advanced stage of ripeness. Olives of larger sizes, with 85-90% flesh, are stored in wooden tubs or in plastic barrels holding 200 Kg of olives. After shaking them down, the containers are filled with drinking water (80-100 litres). They are stored in a cool place and regularly topped up with water.

After 50-60 days, when the flesh can be felt to be easily detachable from the stone if the fruit is pressed between two fingers, the olives are salted by adding 5-6 Kg of salt for every 100 Kg of olives (10-12 Kg per container). Preservation lasts for about 5-6 months, with the containers being regularly topped up with fresh brine containing 10% NaCl.

At the end of the fermentation period, the olives have lost their bitterness, have a very low pH (<4), an unusual winey red colour and outstanding organoleptic characteristics.

The olives are sold loose from glass containers that are first pasteurised using the mature brine or, if necessary, adding fresh brine at the same concentration as the mature brine and suitably acidified.

Total production which, as already stated, is limited to Lazio because of its special micro-climate, is estimated at around 3,000-4,000 tonnes per year and processing takes place in olive-growers' cooperatives or small private factories. The cost of the product on the domestic market is usually almost twice that of untreated black olives in brine.

VARIOUS TRADE PREPARATIONS IN THE UNITED STATES, MOROCCO, SYRIA AND ARGENTINA

The United States mostly produce treated black olives and, in smaller quantities, Spanish-style green olives. Total production, which takes place in California only, amounted to 83,000 tonnes during the six-year period from 1986-87 and 1991-92, practically the same as total annual production in Italy.

During this same six-year period, Morocco had an annual production of 75,000 tonnes, almost the same as Greece. Production is of good quality and is mostly exported.

After Morocco comes Syria which produced during the same period an average of 61,300 tonnes of table olives using very resistant varieties from the Damascus area but especially the dual-purpose varieties, Sourani and Temprani, which are grown in northern Syria.

Argentina is next on the list with an average production of 32,500 tonnes, mainly of Spanish-style green olives. In recent years, Argentina has also begun to produce treated black olives for which it mostly uses the Arauco variety.

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Chapter 9

NUTRITION AND BIOLOGICAL VALUE

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OVERVIEW OF THE NUTRITIONAL BENEFITS OF OLIVE OIL

ROSEMARY STANTON

Throughout the world, the health and nutritional qualities of olive oil are now being recognised. Some would ask why this recognition has taken so long.

In the 1950s, Ancel Keys and Francisco Grande Covian began their classic studies which were to change the way the world thought about coronary heart disease. Through careful analysis of diet, serum cholesterol and the incidence of coronary heart disease in 22 populations in seven countries, their Seven Countries Study reported that populations that ate little saturated fat had low levels of serum cholesterol and a much lower incidence of coronary heart disease. Not all the populations with low saturated fat intake avoided fats, but their fat was in the form of olive oil. This fat contained a predominance of monounsaturated fatty acids.

For some years, the importance of olive oil was ignored in countries outside the Mediterranean region. This is now changing dramatically and it is useful to examine the directions taken by researchers into diet and heart disease.

STAGES IN RESEARCH

THE 1950s AND 60s

Populations who ate olive oil as their major fat were shown to have low serum cholesterol levels and a low incidence of coronary heart disease. At this stage, only total serum cholesterol was measured.

Researchers then began studies using different types of fats and reported that polyunsaturated fatty acids seemed to reduce total serum cholesterol levels better than monounsaturated fats. Saturated fats increased serum cholesterol.

The result of this era was that:

- Polyunsaturated fats were praised
- Saturated fats were damned
- Monounsaturated fats were considered neutral

THE 1970s AND 80s

By this time, millions of people in North America, Australia and parts of Europe had changed to using polyunsaturated vegetable oils and margarines in place of the saturated fats they had used previously.

Researchers then found that cholesterol could be carried on two types of particles: high density lipoproteins (HDL) or low density lipoproteins (LDL). Cholesterol carried in the HDL fraction had a protective role in carrying cholesterol fragments away from the arteries to the liver. Cholesterol carried in LDL particles was the real villain in increasing risk of plaque in the arteries and thus increasing the process of atherosclerosis.

In re-examining dietary factors, it was apparent that saturated fats increased the level of undesirable LDL cholesterol and decreased the protective HDL cholesterol. Polyunsaturated fats, by contrast, decreased the LDL fraction. However, if used in large amounts, polyunsaturated fats could also reduce HDL cholesterol. Monounsaturated fatty acids had an equal ability to reduce LDL cholesterol but could increase the protective HDL fraction. This led to the following:

- Polyunsaturated fats were praised, but only if used in small quantities
- Saturated fats were damned further
- Monounsaturated fats were considered valuable

THE 1990s

Research is now concentrating on the harmful effects of oxidised particles of LDL cholesterol. These are more likely to cause atherosclerosis than any other particle. Researchers now believe that oxidation of one of the polyunsaturated fatty acids, linoleic acid, produces small particles which attach to specific amino acid residues of the LDL protein to form oxidised LDL. This is then likely to form cells which contribute to plaque formation in the coronary arteries. Polyunsaturated fatty acids seem to be more susceptible to oxidation that monounsaturated fats. Various antioxidants also play a role in preventing oxidation reactions.

Trans fatty acids, formed when many types of poly and monounsaturated fats are hardened for use in processed foods and spreads, are also coming under fire. These fats can raise serum cholesterol and may also raise levels of lipoprotein [a], another risk factor for coronary heart disease.

The latest advice is that:

- Polyunsaturated fats may need to be replaced with the safer, less oxidisable monounsaturated fats
- Saturated fats are still considered undesirable
- Monounsaturated fats have been given the place of most importance

To this are added warnings that we should ingest antioxidant substances and avoid trans fatty acids.

If we return to olive oil, we find it is high in monounsaturated fatty acids and also contains valuable antioxidants. So it seems that we have now come full circle back to what Keyes and Grande observed in the 1950s – that olive oil is a safe and nutritious product.

These conclusions have been reinforced by recent research showing the safety of olive oil when used in frying. Some oils with a high content of polyunsaturated fats can form dangerous hydroperoxides when heated. Olive oil does not.

The great variety of antioxidants in olive oil may also be relevant for other health problems where oxidative reactions are undesirable. This includes some types of cancer and various effects of ageing on the body's tissues.

In looking at olive oil overall in scientific research, we must therefore conclude that it is the most useful form of fat available. We should also note that olive oil is much more than a monounsaturated fat. Although most research until now has concentrated on the types of fatty acids present in foods, olive oil also contains a range of antioxidants and flavour ingredients. These may not have known nutritional functions but research is now showing that many anti-cancer compounds found in foods such as fruits and vegetables are not known nutrients. We still have more to learn about olive oil and other similar natural products and we can-not be certain that simply assuming that olive oil is a monounsaturated fat gives it its due credit.

TASTE

Although olive oil has been used for thousands of years in Mediterranean countries, until recently North Americans, Australians and many Northern Europeans regarded it as 'medicine'. Fortunately, such attitudes are changing rapidly and olive oil is enjoying new status as a beautifully-flavoured oil. Many people are also starting to taste olive oil in a similar way to wine and are becoming aware of the wide range of flavours in olive oils made from olives of different varieties, grown in various climates and picked at certain stages of ripeness.

The definite flavour of olive oils is also a boon for those who must restrict all fats in their diet because of problems of excess body fat, diabetes or certain types of cancer. Even a small amount of olive oil can add flavour to a salad or other recipe.

NUTRITION AND BIOLOGICAL VALUE

Mark L. Wahlqvist
Antigone Kouris-Blazos

It is the purpose of this chapter to briefly review our present knowledge regarding the relationship between olive oil consumption, human nutrition and health.

CHEMICAL COMPOSITION OF OLIVE OIL – NOT JUST MONOUNSATURATED

Grades of olive oil

Olives contain 20% oil. Oil is most often extracted by using mechanical pressing combined with heat and/or solvents. The fats are contained in the cells of the plant material. When the material is heated to temperatures of over 200ºC, the cell walls become permeable, which makes it easier for the oil to be pressed out. Heating also makes the oil thinner, which assists its flow. The oil that is left in the residue can be extracted by the use of solvents (hexane, isopropanol, acetone). Once extracted, some oils are then refined – to remove impurities such as some fatty acids and protein fragments, and deodorised and bleached to improve and neutralise the flavour because not all olives are of the same grade and quality.

Olive oils come in a range of grades. The best oil comes from the first pressing whereby only mechanical pressing is used and no heat, known as «cold-pressed» oils. Each successive pressing yields oil of lower grade, which must generally be refined to improve the flavour and keepability. However, the characteristic flavour of these oils is usually lost, they have much higher acidity than virgin oils and this is neutralised with alkali in the presence of solvents.

The oil from the first pressing is labelled «Extra Virgin oil» – it is premium olive oil from the best-quality, barely ripe olives, and is of low acidity. Because it has not been heated, it contains fewer impurities and so usually does not need refining. Its natural flavour is better retained and so are the nutrients. A true cold-pressed oil has a deeper colour (deep yellow or green) and higher viscosity.

«Virgin» oil also comes from the first pressing but heat may have been applied. «Refined» olive oil is obtained by refining «Virgin» oil. «Olive oil» is a blend of «Virgin» and «Refined» oils. The virgin oil is added because it contains natural antioxidants which will protect the lower grade olive oil from becoming rancid. «Olive Pomace» oil is obtained by solvent extraction of the olive residue remaining after mechanical extraction of the «Virgin» oil. It is made edible by refining. A newcomer on the market is «light» olive oil. This term refers to the flavour, not the fat content. «Light» olive oil has a milder, more neutral taste, as it rarely contains any virgin oil and has usually been refined, deodorised and bleached, to further reduce its flavour and colour to a light yellow (Fedeli and Testolin, 1991; Rogers 1990).

Composition of olive oil

Olive oil consists of a saponifiable fraction (triglycerides) 99% and an unsaponifiable fraction (minor components) 1%. In fatty acid composition, no differences exist between «Virgin» and refined oil. The main fatty acid in olive oil is the monounsaturated fatty acid omega 9 oleic (63-83%), followed by the saturated fatty acids palmitic (7-17%), stearic (1,5-5%) and palmitoleic (0.3-3.0%) and polyunsaturated fatty acids omega 6 linoleic (3-14%), and omega 3 linolenic (< 1.5%).

Olive oils from the more southerly, warmer regions of the Mediterranean tend to be higher in linoleic acid than in more northerly regions. The human body cannot synthesize either omega 6 linoleic acid (18:2 n-6) or omega 3 a-linolenic acid (18:3 n-3). Large amounts of these fatty acids are not required to prevent manifestations of deficiency and olive oil provides a low but adequate amount of these fatty acids. The requirements of linoleic and linolenic acid are estimated at 1%-2% and 0.2-0.6% respectively of total energy intake, supplied by 2-3 tablespoons of olive oil/2700 kcal per day (Fedeli and Testolin, 1991).

The unsaponifiable fraction of olive oil contains vitamin E, other antioxidants and non-nutrients, found in greater quantity in the virgin grade (Yoo et al., 1988; Cortesi and Fedeli, 1983).

- *Vitamin E* – 15-17mg/100 ml of oil, of which 90% of the tocopherols present are in alpha form (the most biologically active form); it acts as an antiosidant.

- *Phenolic compounds* – e.g phenols, phenolic acids, polyphenols, have antioxidant activity.
- *Phytoestrogens* – exhibit both oestrogen and anti-oestrogen activity.
- *Sterols* – e.g b-sitosterol, a substance which counters intestinal absorption of dietary cholesterol.
- *Hydrocarbons* – e.g squalene, 0.15mg/100ml of oil, a substance which can inhibit cholesterol synthesis via the enzyme L-CAT; b-carotene, which has vitamin A and antioxidant properties.
- *Terpenic alcohols* – e.g cyclo-arthenol, assists faecal excretion of cholesterol through increased bile acid secretion.
- *Colouring substances* – e.g carotenoids, chlorophyll, have antioxidant activity
- *Aromatic substances* – provide the characteristic aroma and taste of olive oil.

Cooking and olive oil

Olive oil, unlike seed oils, remains stable even at high frying temperatures because of both its antioxidant content and its high oleic acid content, making it less vulnerable to oxidation and subsequent formation of toxic products (e.g peroxides and polymers). Also, studies by Varela et al. (1982) have shown that olive oil does not penetrate the food but remains on the surface, unlike other fats and oils which penetrate most or all of the food. Nor does the digestibility of used olive oil change, not even after 10 repeated fryings of meat or sardines (Varela et al., 1984).

OLIVE OIL IN HEALTH AND DISEASE – NOT JUST HEART DISEASE

THE CHOLESTEROL CONNECTION

Over the last 35 years, nutrition research has produced evidence that polyunsaturated fats (PUFA) were hypocholesterolaemic, that saturated fats (SFA) were cholesterol-raising, and monounsaturated fats (MUFA) were neutral. Saturated fats, such as myristic found in dairy fats and coconut oil and palmitic found in animal fat and palm oil, have been found to raise LDL cholesterol whereas stearic acid in beef fat and chocolate has been found to be neutral but may encourage thrombosis (US National Research Counci, 1989).

The focus has been exclusively on the ratio of PUFA to SFA FATS (i.e P/S ratio), with MUFA receiving little attention; a P/S ratio of 2 was recommended as desirable to counterbalance the cholesterol-raising effect of SFA fat (Keys et al., 1965). Linoleic acid became the preferverd polyunsaturated fat. So for some time, health educators have encouraged us to replace SFA in our diet with PUFA resulting in the current high intake of about 10% of total energy intake in most developed countries.

Recently there has been some concern that a high intake of PUFA may not be as healthy as was originally thought This century there has been a huge human experiment, unprecedented in the history of man, with regards to the high intakes of linoleic acid in vegetable oils. They may have helped to lower heart disease rates but there has also been a rise in cancer death rates. Animal studies and other studies that followed by various groups, raised the suspicion that PUFA may favour tumour development in the presence of chemical carcinogens and that they may lead to immune suppression (Spiller, 1991).

Some studies suggest that, as well as reducing the level of low density lipoproteins (LDL), eating large quantities of PUFA (>10% of total energy intake) can also reduce the level of high density lipoproteins (HDL) in the blood (Mattson and Grundy, 1985; Spiller 1991). But other studies have shown that a usual diet would not contain sufficiently high levels of PUFA for this to occur (Mensink and Katan 1989).

The higher the PUFA intake the higher the intake of antioxidants required (vitamin E requirements can increase 200-fold as PUFA intake increases) due to the vulnerability of these fats to oxidation and formation of free radicals. For this reason PUFA oils are normally accompanied by antioxidants, most of which are required by the oil as a preservative, with little actually available for biological activity in the human body after consumption. In the absence of adequate amounts of antioxidants, large amounts of PUFA in the diet may produce lipid peroxidation and free radicals. Free radicals are now considered to be involved in carcinogenesis and to be the key to the process of atherosclerosis since free radical damage to cholesterol transforms the cholesterol into a potent stimulus for the commencement of arterial lesions (James et al., 1989; Yamamoto et al., 1988).

A competitive interaction exists between the metabolism of fatty acids. Omega 6 linoleic acid suppresses the metabolism of omega 3 fatty acids (e.g linolenic acid, eicosapentaenoic acid and docosahexanoic acid) and vice versa, at the rate limiting step (desaturase enzyme 6D) and they both suppress the metabolism of omega 9 oleic acid (US International Life Sciences Institute Nutrition Foundation, 1990). Thus a high intake of omega 6 linoleic does not allow dietary omega 3 fatty acids to be incorporated into cell and platelet membranes where they exhibit antithrombotic, antiinflammatory and vasodilatory properties. The omega 3 fatty acids have been identified to protect against coronary heart disease due to these properties as well as by lowering blood triglyceride levels, not cholesterol. The benefits of these fats were first identified in population studies of Eskimos and Japanese fishermen, who had a very low incidence of the disease, despite a diet which included large amounts of fatty fish, high in cholesterol (Kromhout et al., 1985).

Recently research has also broadened its focus and taken an interest in MUFA. It now seems that MUFA are just about as effective as PUFA in reducing the level of LDL cholesterol in the blood, but do not lower the level of HDL (Grundy et al., 1988). In support of the claims for MUFA, it has been observed that blood cholesterol levels and the incidence of heart disease are lower in some Mediterranean countries, which consume olive oil almost exclusively, than in other European countries where the total amount of fat in the diet is similar but not obtained from olive oil (Keys, 1980).

In contrast to PUFA, MUFA are more stable and do not oxidise as easily thus not requiring so many antioxidants. The antioxidants found in olive oil are therefore not only available for protecting MUFA from oxidation but also for protecting blood cholesterol from oxidation and damage. Furthermore, unlike omega 6 linoleic acid, omega 9 oleic acid does not compete for the desaturase enzyme. A high background diet of olive oil allows the omega 3 fatty acids to be metabolised into their beneficial by-products. Additionally, if very little omega 6 linoleic acid is consumed, there will be an increase in eicosatetraenoic acid (a breakdown product of oleic acid) which is now known to have potent antiinflammatory action (US Surgeon General's Report 1988; Wahlqvist and Kouris-Blazos, 1991).

The definition of the ultimate mix of fatty acids which is optimal for health and safe in the context of national diets has been under some speculation lately, especially with emerging evidence about the importance of omega 3 fatty acids and oleic acid. Currently it is recommended by most national bodies to consume 7-8% calories as saturated fats (current intake about 13%), 7% calories as linoleic acid (current intake 7-10%) and 10-15% as oleic acid (current intake <10%). No recommendations are given for omega 3 fatty acids. A monounsaturated to polyunsaturated ratio (M/P) or a polyunsaturated + monounsaturated/saturated fat ratio (P+M/S) of 2 is now recommended. In fact, only 1-2% of total energy intake as linoleic acids is required to prevent essential fatty acid deficiency and evidence is emerging that an intake as low as this may be necessary to get the benefits of higher intakes of omega 3 and oleic acids (US National Research Council, 1989; Wahlqvist and Kouris-Blazos, 1991).

However, it may be that not all MUFA-rich oils (e.g almond, rape seed (Canola), macadamia, peanut) have the same effect as olive oil, since the minor components of olive oil may also play an important role.

GLYCAEMIC CONTROL

Garg and co-workers (Garg et al., 1988) compared a high-carbohydrate diet with a high MUFA diet (33% energy intake) in patients with non-insulin dependent diabetes. Better glycaemic control was observed in the patients on the MUFA diet.

OBESITY

Observations on the Cretan cohort of the Seven Countries Study appear to support the notion that the high olive oil Cretan diet is associated with low coronary risk (Keys et al., 1986). However, recent observations in Crete suggest that, in spite of continued high olive oil intake, Cretan men and boys no longer have very favourable blood lipoprotein values (Katan et al., 1987).

One possible explanation for this is obesity, which has become very common in Crete in the past 25 years. This is probably related to the decrease in hard physical labour combined with a continued high intake of fat in the form of olive oil. Short-term clinical studies in humans indicate that high fat diets are associated with weight gain and increase in total energy intake (Lissner et al. 1987). The diet that worked well for Cretan peasants in the 1950s could produce severe overweight in sedentary city-dwellers of the late 1980s, and thus cancel the favourable effects of lipoproteins which olive oil produces in controlled isocaloric experiments. A high MUFA diet is beneficial as long as total fat intake is kept within limits or exercise levels are maintained or increased to avoid obesity.

CANCER

The weight of the evidence in several types of epidemiological studies indicates that a high-fat (especially saturated fat) intake coupled with low plant food intake is associated with increased risk of cancer, with little or no correlation with PUFA intake. This has been explained on the basis that human diets normally contain enough linoleic acid to satisfy the threshold requirement for tumour promotion observed in animal studies.

Experiments in animals suggest a twofold requirement in promotion of carcinogenesis by dietary fat. The dietary fat must provide a certain amount of linoleic acid (4-5% total energy intake) and when this requirement is satisfied, the promoting effect of additional dietary fat appears to be unrelated to the type of fat. The amount of linoleic acid in olive oil is insufficient for maximum promoting activity (Carroll et al., 1986).

Two recent case-control studies in Europe suggest that MUFA may actually have a protective effect against colorectal cancer, but this finding needs further confirmation (Tuyns et al., 1987). Olive oil in animal models and in the Mediterranean region where it is the main component of fat intake, appears to have a neutral or protective action on hormone metabolism and thus does not have an enhancing effect on endocrine-related cancers (prostate, breast, ovary) (Weisburger, 1991). It has been postulated that this may be related to phytoestrogens found in the Mediterranean diet, namely in vegetables, legumes and olive oil which may assist in decreasing endogenous oestrogen production (James et al., 1989; Adlercreutz et al., 1987). The antioxidants found in olive oil may also be protective against free radical damage and carcinogenesis.

OSTEOPOROSIS

Limited evidence exists on the effect of olive oil on bone mineralization. Laval-Jeantet et al. (1980) were able to prove with an animal model that the best bone mineralization was obtained on an intake of MUFA supplemented by a minimum amount of PUFA (which is what is normally found in olive oil). The phytoestrogens found in olive oil require further investigation to determine their possible role in preventing bone loss by blocking sex hormone-binding globulin and thus increasing the availability of free oestrogen which favours bone mineralization.

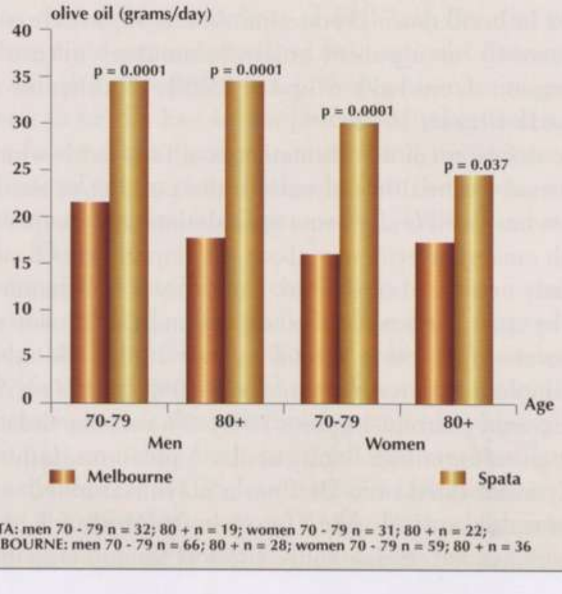
CONSUMPTION OF OLIVE OIL

According to food balance sheets published by FAO 1984, Greece has the highest per capita consumption of olive oil (60g/day), followed by Italy (30g/day) and Spain (25g/day). However, intake of olive oil has decreased over the years whereas animal fats and intake of other vegetable oils has increased. The food balance sheets also reveal a doubling of meat, egg and sugar availability since the 1960s, cereal availability has also decreased by a third, availability of pulses has halved, whereas fruit and vegetables have almost doubled (Trichopoulou et al., 1990). Trichopoulou (1991) reports that these trends imply a progressive «northernization» of the Mediterranean diet and that further evidence pointing in the same direction comes from Household Budget Surveys (Trichopoulou, 1989) and from ad hoc studies in several Mediterranean countries (Ferro Luzzi and Sette, 1989).

There is also evidence from the Seven Countries Study that olive oil intake has decreased during the last 20 years in Greece (Crete and Corfu) along with bread, other cereals and legumes whereas meat, animal fat, cheese and alcohol have increased (Aravanis and Loannidis, 1984). This decrease in olive oil consumption is reflected in the fatty acid composition of the diets of subjects studied in Crete (Kafatos et al., 1991). In 1960 percent total energy from fat was 40%, 8% SFA, 29% MUFA, 3% PUFA with a P+M/S ratio of 4. In 1988 the percentage total energy intake from fat had decreased to 36%, SFA had increased to 10.2%, MUFA had decreased to 17%, PUFA remained unchanged at 3% and the P+M/S ratio had dropped dramatically to 1.96. These dietary changes parallel the observed increase in the total serum cholesterol from 4.7mmol/l in 1962 to 6.4mmol/l for 181 Cretan men aged 40-60 in 1988, i.e a 36% increase.

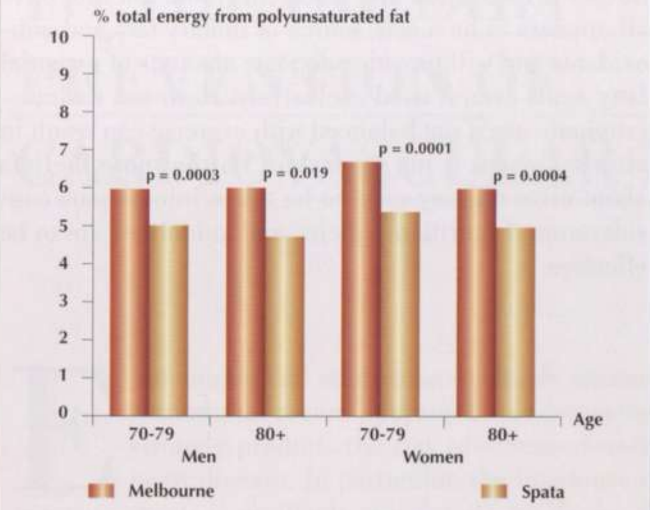
Studies on elderly Greeks in Greece and Australia (Wahlqvist and Kouris-Blazos, unpubl. data) have shown that olive oil consumption further decreases on migration. A sample of 104 Greeks (51 men and 53 women) aged over 70 were studied in 1988 in Spata, Greece (20 Km from Athens) and compared to a sample of 189 elderly Greek subjects (94 men and 95 women)

FIGURE 1
OLIVE OIL CONSUMPTION
Comparison between Spata (Greece) 1988 and Melbourne (Australia) 1990-1991



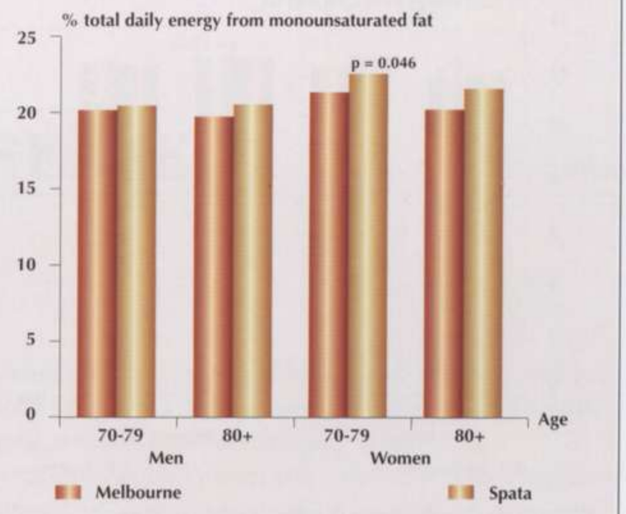
SPATA: men 70 - 79 n = 32; 80 + n = 19; women 70 - 79 n = 31; 80 + n = 22;
MELBOURNE: men 70 - 79 n = 66; 80 + n = 28; women 70 - 79 n = 59; 80 + n = 36

FIGURE 2
DAILY ENERGY INTAKE OF POLYUNSATURATED FATS
Comparison between Spata (Greece) 1988
and Melbourne (Australia) 1990-1991



SPATA: men 70 - 79 n = 32; 80 + n = 19; women 70 - 79 n = 31; 80 + n = 22
MELBOURNE: men 70 -79 n = 66; 80 + n = 28; women 70 - 79 n = 59; 80 + n = 36

FIGURE 3
DAILY ENERGY INTAKE OF MONOSATURATED FATS
Comparison between Spata (Greece) 1988
and Melbourne (Australia) 1990-1991



SPATA: men 70 - 79 n = 32; 80 + n = 19; women 70 - 79 n = 31; 80 + n = 22
MELBOURNE: men 70 - 79 n = 66; 80 + n = 28; women 70 - 79 n = 59; 80 + n = 36

over 70 that had migrated to Melbourne, Australia. Olive oil consumption was found to be significantly lower ($p<0.0001$) in the migrant group (mean intake 18g/day) compared to the Spata elderly (mean intake 30g/day) (see figure 1). This has also been reported in the Levkadian Migrant Health Study, where a total of 1041 subjects of all ages were studied – 488 on the Greek island of Levkada and 533 in Melbourne (of which 60% were related to subjects in Levkada). The migrants reported a mean consumption of olive oil per household per week of 1.3 litres compared to the 3.9 litres per household per week in Levkada (Powles et al., 1988).

It appears that the migrant elderly Greeks have substituted their olive oil with other vegetable oils (mean intake 4g/day) ($p<0.01$) and margarines (mean intake 3g/day) ($p<0.001$) which were not consumed in the Spata sample.

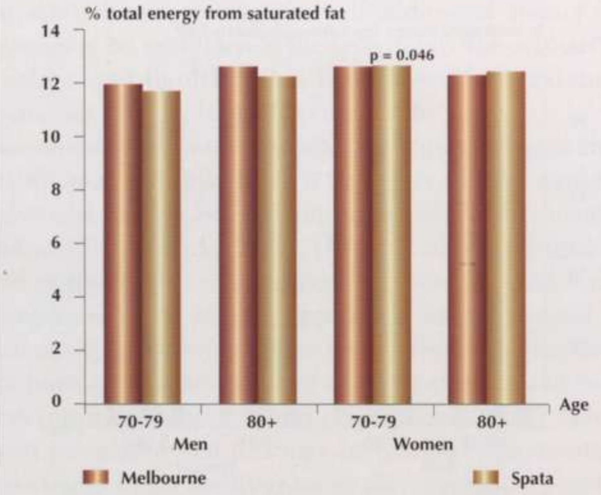
This was also reflected in the percentage energy from PUFA which was significantly higher in the migrant elderly (mean 6%) compared to the Spata elderly (mean 4%) ($p<0.001$) (see figure 2). The percentage energy intake for total fat was 42%, SFA 12.4%, and MUFA 20.5% which were not significantly different from the Spata elderly (see figures 3 and 4). The P + M/S ratio (mean 2.2) was also similar in both sites (see figure 5).

The Euronut-Seneca study also included a sample of 60 Greeks aged 75 in Markopoulo (actually located near Spata) and 85 Greeks aged 75 on the island of Crete (Euronut SENECA investigators, 1991). The fatty acid intake of these elderly was very similar to the Spata elderly – percentage total energy intake from fat was 43%, SFA 10%, MUFA 20%, PUFA 4% and the P + M/S ratio 2.5.

FOOD BELIEFS ABOUT OLIVE OIL

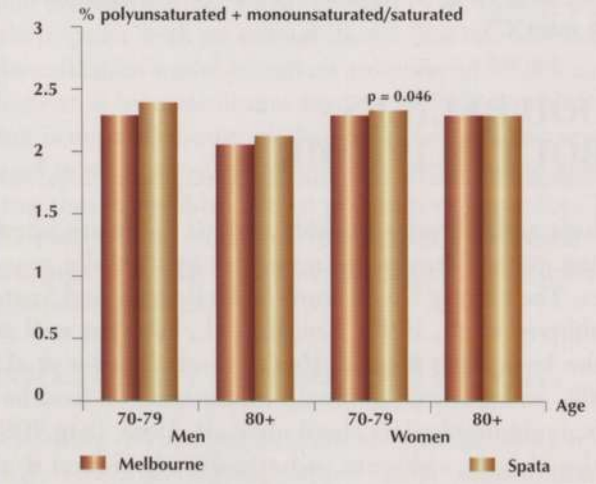
Beliefs and attitudes towards various foods are interesting as they may explain current food intake practices. The elderly Greek study in Melbourne and Spata (Wahlqvist et al., 1991; Kouris et al., 1991) as well as in the Levkadian Migrant Health Study (Powles et al., 1988), endeavoured to obtain information on food beliefs, including beliefs about olive oil. More than 70% of the elderly subjects in both sites believed that «olive oil should be eaten in liberal quantities preferably added to food once cooked and that margarine, butter and other oils are best avoided because they are not as healthy as olive oil». Additionally, 60% believed that olive oil was not fattening. In the Levkadian Migrant Health Study 40% of the Levkadians, and 50% of the emigrants believed that oil was not fattening. Similarly to the elderly study, 88% of Levkadians and 73% of the migrants believed olive oil was very good for health.

FIGURE 4
DAILY ENERGY INTAKE OF SATURATED FATS
Comparison between Spata (Greece) 1988
and Melbourne (Australia) 1990-1991



SPATA: men 70 - 79 n = 32; 80 + n = 19; women 70 - 79 n = 31; 80 + n = 22
MELBOURNE: men 70 - 79 n = 66; 80 + n = 28; women 70 - 79 n = 59; 80 + n = 36

FIGURE 5
RATIO OF POLYUNSATURATED +
MONOUNSATURATED/SATURATED FATS
Comparison between Spata (Greece) 1988
and Melbourne (Australia) 1990-1991



SPATA: men 70 - 79 n = 32; 80 + n = 19; women 70 - 79 n = 31; 80 + n = 22
MELBOURNE: men 70 - 79 n = 66; 80 + n = 28; women 70 - 79 n = 59; 80 + n = 36

CONCLUSION

The ultimate mix of fatty acids which is optimal for health and safe in the context of national diets needs further investigation and research. In the interim, olive oil appears to be a safe source of dietary fats and antioxidants and will provide adequate amounts of essential fatty acids even if used exclusively. However, its indiscriminate use if not balanced with exercise can result in obesity, which is not desirable. Furthermore, beliefs about olive oil may need to be taken into serious consideration if nutrition policies and guidelines are to be effective.

A RATIONAL APPROACH TO THE DIETARY PREVENTION OF CARDIOVASCULAR DISEASE

ANTONIO PAGNAN

Epidemiological studies have clearly demonstrated that serum lipoprotein concentration strongly predicts the risk of atherosclerotic heart disease. In particular, the incidence of coronary events is positively associated with the levels of total and LDL cholesterol both in population comparisons and in studies conducted within populations. As for the role of HDL cholesterol in the subsequent development of coronary heart disease, studies within populations have consistently shown a protective effect.

The level of plasma lipoproteins is influenced by environmental factors such as cigarette smoking, physical activity, alcohol consumption and the composition of the diet. With respect to diet, it has been amply documented that an excess of calories, saturated fatty acids and cholesterol promotes a substantial increase in LDL cholesterol levels. The hypercholesterolemic effect of saturated fatty acids is predicted and quantified by the Keys and Grande equation. In recent years, however, the results of important dietary studies have clarified the specific role of different saturated fatty acids in lipid metabolism. In fact, we now know that not all saturates exhibit a cholesterol-raising effect. In particular, stearic acid has been shown not to increase plasma cholesterol, probably because it is rapidly converted to oleic acid. Moreover, there is evidence that replacing saturated fatty acids with oleate is as effective as linoleic acid in reducing LDL cholesterol.

The importance of diet for the control of risk factors for atherosclerotic vascular disease is confirmed by recent interesting observations suggesting that certain dietary fatty acids may also contribute to the regulation of blood pressure. These data show that the substitution of saturated fatty acids in the diet with polyunsaturated or monounsaturated fatty acids leads to a significant hypotensive effect. It is now widely agreed that the guidelines for dietary control of hypercholesterolemia are the following: reduced intake of calories, cholesterol and saturated fatty acids, and increased intake of monounsaturated and polyunsaturated fatty acids.

In order to achieve this goal, there are three different options:

1) American Heart Association - Phase I diet. Fats 30% of total calories (10% saturated (S), 10% monounsaturated (M), 10% polyunsaturated (P)), carbohydrates 45%, protein 15%, cholesterol ≥ 250 mg/day.

This 'sensible' diet has been widely recommended for the prevention of ischemic heart disease although several researchers consider it inadequate to obtain maximal reduction of LDL levels. This goal might be achieved by further decreasing the amount of fat to 20% of total calories, as proposed in the American Heart Association Phase III diet.

2) American Heart Association - Phase III diet (rich in carbohydrates). Carbohydrates 65% of total calories, fats 20%, protein 15%, cholesterol 100 mg/day.

This type of diet efficiently reduces the level of LDL cholesterol. However, the high intake of carbohydrates might have the adverse secondary effects of increasing serum triglycerides with a parallel decrease of plasma HDL cholesterol levels, and increasing the atherogenic risk. Moreover, the low fat content makes this type of diet not very appetising.

3) High fat and high polyunsaturated fatty acid (PUFA) diet. Fats 40% of total calories, PUFA 17%, carbohydrates 45%, protein 15%, cholesterol <300 mg/day.

In the past, this type of diet was widely recommended and, as predicted by the Keys and Grande equation, it significantly reduces total cholesterol and LDL cholesterol plasma levels. However, when the PUFA content is too high (17%), a lowering of HDL cholesterol is also observed and possible side effects might be expected affecting the immune system, increasing proneness to gallstone formation and promoting carcinogenesis.

4) High fat and high monounsaturated fatty acid (MUFA) diet. Fats 35% of total calories, MUFA 15%, carbohydrates 50%, protein 15%, cholesterol <300 mg/day.

Recent studies have confirmed that by substituting monounsaturated fatty acids (oleic acid) for saturated fatty acids in the diet, the lowering of plasma LDL cholesterol is equal to that obtained with polyunsaturated fatty acids, without altering or even increasing plasma HDL cholesterol levels. Moreover, diets enriched in oleic acid, administered as olive oil, are considered to be the safest because olive oil has been consumed in large amounts since ancient times. Finally, there is substantial clinical and epidemiological evidence that dietary enrichment with olive oil could determine a lowering of blood pressure, thus improving the cardiovascular risk.

Although fats and carbohydrates represent the main dietary components that may influence lipid metabolism, there is an interesting line of research showing that the amount and quality of proteins might also affect serum lipoprotein levels. In fact, while animal proteins seem to be detrimental for lipid metabolism, vegetable proteins such as soybean protein, when replacing animal proteins in the diet, cause a decrease in serum atherogenic lipoproteins in hypercholesterolemic humans and animals.

Another dietary component which favourably influences serum lipoprotein is vegetable fibre. Its addition to the diet in large quantities decreases serum levels of total cholesterol and glucose, probably by reducing their intestinal absorption.

Finally, it is important to stress the point that antiatherogenic diets, due to the limitation of animal fat and milk products, do not contain sufficient amounts of calcium, thus favouring the onset of osteoporosis. The presence of adequate amounts of calcium and potassium in the diet, together with sodium restriction, is advisable not only for the prevention of osteoporosis, but also for a better control of hypertension, which is associated frequently with hyperlipidemia.

In conclusion, based on current scientific knowledge, we consider that the high MUFA diet is the most appropriate for the prevention of atherosclerotic vascular disease. The nutritional model which best corresponds to the chemical composition of this diet is the «Mediterranean diet» of which olive oil is one of the main components.

DIET AND CARDIOVASCULAR DISEASES

ALI OTO

In recent years there has been much discussion on the relation between diet and health. Many recommendations have targeted the composition of the diet. Dietary fats have been the main topic of these discussions being the source of about 40% of energy intake in a typical western diet. Diet-heart hypothesis depends on the support of the studies confirming the idea that dietary fats may be causative in the development of atherosclerosis. On the other hand the main cause of coronary heart disease is atherosclerosis of the coronary arteries. Coronary heart disease still constitutes the leading cause of death in industrialized countries.

Atherosclerosis develops slowly and insidiously over many years in apparently healthy persons and the disease manifests itself only when it causes angina pectoris, myocardial infarction, heart failure or sudden death.

Epidemiological, clinical, genetic and laboratory animal studies unequivocally indicate that an elevated blood cholesterol is associated with an increased risk of coronary atherosclerosis and coronary heart disease. Among more than 30 studies, the Framingham Heart Study, Multiple Risk Factor Intervention Trial, Lipid Research Clinics Coronary Primary Prevention Trial and Helsinki Heart Study are key studies demonstrating the link between cholesterol and coronary heart disease. Meta analysis of trials of cholesterol lowering in patients with established disease have demonstrated significant declines in subsequent coronary events and in coronary heart disease and cardiovascular disease death rates as well as borderline significant declines in all cause mortality. Additionally, regression studies using serial coronary angiograms have demonstrated the arrest of progression and even regression of coronary atherosclerosis with cholesterol lowering induced by drugs, diet or ileal bypass surgery. Both clinical trials and regression studies have also shown that cholesterol lowering can be beneficial even in patients with advanced disease.

The reduction in recurrent coronary event rates by cholesterol lowering compares favorably with other medical therapies, including aspirin and beta-blocker in secondary prevention from subsequent events.

LDL cholesterol is always the primary target of intervention. HDL cholesterol and triglycerides are more problematic targets of therapy. In regression studies, regression was associated with both lowering of LDL and increase in HDL cholesterol levels. A reasonable approach is to attempt to increase HDL cholesterol levels whenever possible, particularly when triglyceride levels are elevated besides targeting the increased LDL levels.

A large body of evidence shows the powerful link between diet and coronary heart disease and that diet is a significant determinant of a person's serum cholesterol level. Retrospective surveys of coronary heart disease in large population studies have revealed that fat intake in countries with low coronary heart disease rates is considerably lower than in regions with higher rates. Moreover, it has been reported repeatedly in epidemiological studies that high intakes of saturated fatty acids, cholesterol and excess calories leading to obesity are causally related to atherosclerotic cardiovascular disease. In addition to the epidemiological studies, clinical studies in metabolic wards have clearly shown that dietary saturated fatty acids raise serum total and LDL cholesterol levels whereas replacement of saturated fatty acids by carbohydrates, PUFA or MUFA will decrease serum cholesterol by a predictable amount.

The Seven Country Study provides the strongest evidence that diets high in saturated fatty acids increase the risk of coronary heart disease. The 15-year follow-up in this study pointed out a 32-fold variation in deaths from coronary heart disease in Europe, with the lowest incidence being in Crete and highest incidence in Finland. Although the fat intake constituted almost 40% of the total calories in both populations, in Crete the typical Mediterranean diet which offers entirely monounsaturated fatty acids from olive oil was the hallmark of diet. Other reports have also confirmed these observations. The serum cholesterol level in the Mediterranean basin was found to be lower in parallel to exclusive olive oil intake as compared to the Western Countries. Interestingly enough, recently with the change in dietary habits, and the departure from the typical Mediterranean diet and consequently lower olive oil consumption, serum cholesterol level has been seen to increase in the Mediterranean Countries.

It has been obvious from many reports over the past decade that the unsaturation of the dietary fatty acids affect the plasma cholesterol level. In this context monounsaturated fatty acids have been shown to be as effective as polyunsaturated fatty acids in lowering LDL cholesterol. In addition to this, plasma HDL levels are not usually changed or increased in the case of monounsaturates as compared to polyunsaturates. In comparison, when monounsaturated fatty acids with carbohydrates were used to replace the dietary saturated fatty acids, both were shown to lower total cholesterol and LDL to a similar degree. However, monounsaturated fatty acids were slightly superior to carbohydrates. The carbohydrates diet raised triglyceride levels and lowered HDL levels, whereas monounsaturates had no effect on either. Therefore the available data are in favour of monounsaturates to replace saturated fatty acids as an energy source in daily diet. On the other hand, oleic acid-rich olive oil has also been suggested to reduce platelet aggregation, increase L-CAT enzyme activity and lower high blood pressure. The hypotensive effect of olive oil has been attributed to the increased synthesis of prostacyclin by olive oil.

Based on the Recommendations of the American Heart Association and The Study Group-European Atherosclerosis Society, the following suggestions for the general population and high risk individuals can be made:

a) Control of overweight by decreasing energy intake and by exercise.
b) Reduction of total fat intake from 40% to 30%.
c) Reduction of the intake of saturated fatty acids to 10% of total dietary energy. Approximately 10% of total energy should come from polyunsaturated and almost 10% from monounsaturated fatty acids.
d) Reduction of dietary cholesterol to less than 300 mg/day.
e) Increased consumption of complex carbohydrates.
f) Increased intake of fruit, vegetables and cereal fibre.

ATHEROSCLEROSIS:

FAT OXIDATION AND CORONARY ARTERY DISEASE

ALI OTO

Epidemiological studies have revealed five major risk factors for atherosclerosis and atherosclerotic heart disease; high plasma cholesterol levels, cigarette smoking, high blood pressure, genetic predisposition and age. As far as serum cholesterol is concerned, the risk has been primarily linked with low density lipoproteins (LDL) which carry 70 % of the plasma cholesterol, whereas plasma concentration of high density lipoproteins (HDL) appears to be inversely related to death from coronary heart disease. The unequivocal acceptance of elevated LDL levels as a risk factor for coronary artery disease has revealed the necessity of lowering plasma LDL levels.

The pathogenesis of atherosclerosis has been extensively studied and the cellular aspects increasingly characterized. Fatty streaks, fibrous plaques and complicated plaques are the pathological hallmarks of atheroslerosis. These lesions insidously progress and symptoms appear to develop when the plaque luminal surface destabilizes. The major cellular contributors to plaque development are monocytes/macrophages, endothelial cells, smooth muscle cells and, to a lesser degree, lymphocytes and platelets. They interact in a complicated fashion. Growth factors and cytokines produced by these cells are also of great importance for cell to cell interaction. Hemodynamic factors contribute to atherogenesis at preferential sites within the arterial vasculature, presumably by effects on cellular mechanism.

FAT OXIDATION: MECHANISMS AND ATHEROGENECITY

The evidence that oxidative modification of LDL may play an important causative role in atherosclerosis has been increasing rapidly in recent years. As a matter of fact lipid peroxides formed by peroxidation of unsaturated fatty acids were first detected in atherosclerotic human aortas more than 30 years ago and correlate with the severity of the disease. Some authors have been sufficiently convinced by the already available epidemiological, biochemical and experimental animal data to propose clinical intervention trials to test the oxidative modification hypothesis. Thus, whatever the mechanism by which LDL promotes atherogenesis is, the main issue of interest will be to further inhibit the atherogenic process by inhibiting the oxidation of LDL.

The general concept regarding atherogenic process is that the accumulation of cholesterol by macrophages within intima-foam cell formation is an early step. Athough LDL uptake by the cells is through the classic LDL receptor, this receptor is expected to be downregulated when the cellular need for cholesterol is met. However, recent observations have suggested that human macrophages do not have classic LDL receptors and that other receptors might be involved in the uptake of LDL by macrophages. Therefore the possibility of the biochemical modification of LDL and the uptake of this modified LDL by an alternative receptor mechanism has arisen and has been termed the «scavenger receptor pathway». There have been many careful studies supporting this concept recently.

However it is not yet known how LDL oxidation is initiated. The foam cells of atherosclerosis which are macrophages produce oxygen radicals as a part of their role in combat to kill microorganisms. The same process may be applied to the oxidation of lipids or lipoproteins in atherosclerosis. Therefore these free radicals have been suggested as the responsible mediators for the modulation of LDL. Lipid peroxidation can occur beginning with a free radical mediated hydrogen atom abstraction from a polyunsaturated fatty acid group in the LDL and this is followed by the formation of a peroxyl radical with molecular oxygen. In the absence of antioxidants, the peroxyl radical will abstract another hydrogen atom from another polyunsaturated fatty acid group to form a fatty acid hydroperoxide and another fatty acid carbon-centered radical, finally resulting in an uncontrolled chain reaction. Furthermore the reaction may accelerate because the hydroperoxide products themselves are a potential source of further radicals. On the other hand, LDL carries within it a number of natural antioxidants (Vit E, beta carotene, lycopene, ubiquinol etc) that can trap free radicals and prevent the chain reaction from starting or limit its extent. Therefore increasing the antioxidant content of the LDL would be one way to interfere and possibly prevent the undesirable consequences of LDL oxidation.

The initial interest in oxidized LDL focused on its ability to promote cholesterol accumulation in macrophages. However, oxidative modification of LDL is accompanied by a number of compositional and structural changes, including increased electrophoretic mobility, increased density, fragmentation of apolipoprotein B, hydrolysis of phosphatidylcholine, derivatization of lysine amino groups, and generation of fluorescent adducts due to covalent binding of lipid oxidation products to apo B. Recently it has become clear that oxidized LDL is potentially more atherogenic than native LDL in many different ways. Oxidation of LDL has been shown to result in significant changes in its biological properties that could have pathogenetic importance. Oxidized LDL is rapidly taken by macrophages and causes cholesterol accumulation (foam cell formation) and it is chemotactic for monocytes but inhibits macrophage motility. Products of oxidized LDL are cytotoxic; this feature may be responsible for the endothelial injury and thrombotic events. It may promote vasospasm by inhibiting the release of the endothelium derived relaxing factor. On the other hand minimally oxidized LDL has been shown to alter gene expression in arterial cells and induce endothelial cells to express colony-stimulating factors and monocyte chemotactic protein 1 which may promote macrophage differentiation. All of these features have indicated that LDL oxidation is a complex process and most probably the degree of oxidation defines the effects of modulated LDL creating a wide spectrum of end results in favor of atherogenicity.

PREVENTION OF ATHEROSCLEROSIS: POSSIBLE ROLE OF ANTIOXIDANTS.

It is obvious from the above-mentioned explanations that interventions inhibiting the oxidation of LDL should also inhibit the atherogenic process. However, there are still many unknowns in the field of antioxidants. Theoretically antioxidants such as vitamin E, beta carotene or ubiquinol-10 or ascorbic acid(as an aqueous phase antioxidant) can be given. In addition, the inhibition of cells to oxidatively modify LDL may achieve the same purpose. Although there are no published double blind, controlled, large scale studies to establish the value of antioxidant supplementation, the evidence from epidemiological studies is suggestive.

We also have evidence from nutritional and biochemical studies which indicate that diet can modulate the susceptibility of plasma LDL to undergo oxidative modification by affecting the concentration of polyunsaturated fatty acids and antioxidants in the lipoprotein particle. In this regard diets rich in oleic acid compared with diets enriched with polyunsaturated fatty acids have been shown to produce LDLs which are very rich in oleic acid and remarkably resistant to oxidation, which could provide additional protection against atherosclerosis. The antioxidants, Vitamin E and beta carotene found in olive oil may also have an important part to play in this process.

In conclusion, although there is still a significant lack of understanding of the oxidative modification hypothesis in atherosclerosis and the effects of antioxidants in prevention, the experimental and animal evidence and epidemiological data create a growing body to promote studies to define optimal regimes for the antioxidant protection of LDL in humans. Demonstration of the precise protective role of diet rich in oleic acid will be of particular interest.

ATHEROSCLEROSIS:

FATTY ACID OXIDATION AND CORONARY ARTERY DISEASE

ANDREA BONANOME

Elevated levels of plasma LDL-cholesterol are one of the major risk factors for atherosclerosis. In recent years, qualitative changes of LDL, and, more specifically, oxidative modification, have been shown to enhance the atherogenic properties of these lipoproteins.

Oxidation of LDL is thought to take place within the arterial wall, once the lipoprotein molecules penetrate through the endothelial barrier. In the subendothelial spaces, lipid peroxidation of LDL ensues from the action of endothelial cells, macrophages, and smooth muscle cells. Oxidized LDL have been shown to be cytotoxic in vitro, and possibly could induce functional or even structural damage to the endothelium, whereas endothelial injury has been shown to be the forerunner of clear-cut atherosclerotic lesions. Furthermore, oxidized LDL exert a chemotactic stimulus towards monocytes, which in turn migrate to the subendothelial spaces. Here, monocytes become macrophages that take up avidly LDL, through the acetyl-LDL receptor, and transform themselves into foam cells, which are typical components of atherosclerotic lesions.

Experimental data on animal models have given further support to the theory that lipid peroxidation of lipoproteins plays an important role in atherogenesis. For instance, the progression of atherosclerotic lesions in rabbits has been shown to be counteracted by the administration of antioxidants such as probucol.

The first target of peroxidation are polyunsaturated fatty acids of LDL. This process can be inhibited by antioxidants that are commonly present in the LDL molecule, such as vitamin E. Thus, lowering the content of antioxidants in LDL, and/or increasing the concentration of polyunsaturated fatty acids in the molecule should promote the tendency of LDL particles to undergo oxidative modification.

Several studies have shown that dietary supplementation with antioxidants leads to a decrease in the proneness of LDL to oxidation. Also, epidemiological data suggest that the incidence of coronary heart disease is in fact inversely correlated with the average dietary intake of antioxidants and their plasma levels. Hence, a first approach to reduce the chances of LDL to undergo oxidative modification could consist in a greater intake of antioxidants such as vitamin E or C. Whether this will lead to a reduction of cardiovascular events, of course, remains to be assessed.

An alternative way to reduce the sensitivity of LDL to oxidation might consist of the partial substitution of polyunsaturated fatty acids in the lipoprotein. This could be achieved by changing the fatty acid composition of the diet, which has been shown to influence the fatty acid composition of LDL. Saturated fatty acids and monounsaturated fatty acids do not contain any methylenic group, which is the attack site for free radicals, within their molecule. Thus, the replacement of polyunsaturates with either one of these families of fatty acids should result in a lower susceptibility of LDL to oxidation.

The substitution of saturates in lieu of polyunsaturates obviously is unwanted since saturated fatty acids are known to raise plasma cholesterol. On the contrary, monounsaturated fatty acids have been shown to lower plasma cholesterol as much as polyunsaturates; thus, a diet rich in monounsaturated fatty acids could have the advantages of lowering plasma cholesterol without increasing the proneness of LDL to oxidation.

Olive oil is very rich in oleic acid and, furthermore, contains considerable amounts of antioxidants such as vitamin E and polyphenols. The employment of olive oil in the preparation of cholesterol-lowering diets could therefore serve the double purpose of achieving a hypocholesterolemic effect while, at the same time, reducing the susceptibility of plasma LDL to oxidation. Recent studies indeed support this hypothesis and, although their clinical relevance still needs to be ascertained, these data could further strengthen the usefulness of the «Mediterranean diet» for the prevention of cardiovascular disease.

DIET AND PERIPHERAL ARTERIAL OCCLUSIVE DISEASE:

THE ROLE OF POLY-, MONO-, AND SATURATED FATTY ACIDS

Klea Katsouyanni
Yannis Skalkidis
Eleni Petridou
Antonia Polychronopoulou-Trichopoulou
Walter Willett
Dimitrios Trichopoulos

Atherosclerosis is a diffuse nosologic entity[1]. Patients with coronary heart disease are five times more likely to develop overt peripheral arterial occlusive disease and, conversely, patients with peripheral arterial occlusive disease are four times more likely to develop coronary heart disease[2-4].

There is overwhelming evidence that serum cholesterol and, in particular, low density lipoprotein cholesterol and very low density lipoprotein cholesterol are important risk factors for coronary heart disease[5], and there is a vast amount of literature concerning the relation between diet and serum lipids[6]. By contrast, there are few studies concerning the relation between diet and coronary heart disease[7-10], and the results remain inconclusive[11-13]. Furthermore, we are not aware of studies concerning the association between dietary patterns and peripheral arterial occlusive disease, even though atherogenesis may be more evident in peripheral than in coronary arteries[4]. We report the results of a study concerning the association between diet and peripheral arterial occlusive disease in Greece. Particular emphasis was given to the possible role of olive oil as a dietary factor that may limit the occurrence of atherosclerosis. Olive oil is an important component of the Mediterranean diet, and Mediterranean countries are known to have low coronary heart disease incidence and mortality[14,15].

This article focuses on the analysis of nutritional data provided by a series of 100 patients with peripheral arterial occlusive disease and 100 hospital controls. Data concerning non-nutritional risk factors and descriptive parameters have been published[16]. Briefly, cases were patients with a principal diagnosis of peripheral arterial occlusive disease consecutively admitted, over an 18-month period, to a major teaching hospital in Athens. This is one of five general teaching hospitals in Athens and one of 20 major hospitals in the Greater Athens Area. The hospital is situated in the northern part of the city, but the catchment area is not easily definable, since the referral patterns are heavily influenced by decisions of administrators of several health funds, as well as by physicians' choices and patients' preferences. Peripheral arterial occlusive disease patients had to have specified abnormal findings in the Doppler ultrasound flowmeter examination and in the aortic or femoral arteriography; controls were patients randomly chosen among those hospitalized in the same period as the index cases for 14 different conditions requiring minor surgical care. Among these conditions the most common were hernias (25 patients), fracture or traumatic injuries (17 patients), cataract (14 patients), appendicitis (8 patients), and varicose veins (7 patients), followed by simple goiter (5 patients), external abscesses (4 patients), other skin conditions (5 patients), various ear, nose, and throat conditions (7 patients), and others (8 patients). Cases and controls were not matched for age but were frequency matched for sex. Controls were excluded if they had clinical history, clinical symptoms, or clinical signs of peripheral arterial occlusive disease. All interviews were conducted by one of the authors (Y.S.). The interview was always conducted directly with the patient before the first admission discharge. In the interview, data concerning demographic, socioeconomic, and medical variables were recorded and dietary histories were obtained. All patients were asked to indicate the average frequency of consumption, over a period of 1 year before the onset of the present disease, of 110 food items or beverage categories according to precoded levels of intake per month, per week, or per day. The frequency of consumption of different food items was eventually quantified approximately in terms of the number of times per month the food was consumed, as done by Graham et al.[17], Dales et al.[18], and Trichopoulos et al.[19]. Thus, a value of 30 was assigned to food items consumed almost every day; a value of 4 to those consumed about once a week; a value of 2 to those consumed at least once a month but not every week; and a value of 0 was assigned to food items rarely or never consumed.

Nutrient intakes for individuals were estimated by multiplying the nutrient contents of a selected typical portion for each specified food item by the frequency that the food was eaten per month and adding these estimates for all food items. Food composition data were based primarily on values obtained from the University of Massachusetts nutrient database. Values for special Greek foods were computed from typical recipes[20]. Specifically, the following nutrient intakes were estimated: protein (g), total fat (g), saturated fat (g), monounsaturated fat (g), polyunsaturated fat (g), cholesterol (mg), carbohydrates (g), sucrose (g), crude fiber (g), vitamin C (mg) and total energy intake (kcal).

In order to investigate the association of the estimated nutrient intakes to peripheral arterial occlusive disease, a preliminary analysis was undertaken based on the comparison of the frequency distributions of cases and controls by levels of individual nutrients. Three levels were used, taking as cutoff points the tertiles of the distribution of all subjects (cases and controls combined) for every individual nutrient. Since, however, most nutrients are positively correlated with total energy, two approaches were used to control the potential confounding effect of energy intake. First, calorie-adjusted nutrient intakes were computed using simple linear regression models with a specific nutrient as the dependent variable and caloric intake as the independent variable. Residuals were than calculated[21]. These calorie-adjusted nutrient intakes were then alternatively or simultaneously used as independent variables, together with total energy intake, in multiple logistic regression models. This procedure was used to evaluate the nutrient-disease association, controlling for total energy intake. Odds ratio were estimated from the logistic models. Second, the density of a specific macronutrient, expressed as the percentage of total energy intake, as well as total energy intake, was used in the same regression model. This model, referred to as the «multivariate nutrient density model»[22], allows assessment of the effect

TABLE 1
CHARACTERISTICS OF 100 PATIENTS WITH PERIPHERAL ARTERIAL OCCLUSIVE DISEASE AND 100 COMPARISON PATIENTS: ATHENS, GREECE, 1988

	Risk factors							
	Age (n)				Sex (n)			
	≤49 years	50-59 years	60-69 years	≥70 years	Male	Female	Schooling (years)	Weight (kg)
Peripheral arterial occlusive disease	3	18	32	47	88	12	7±0.04*	74±0.12
Controls	5	31	31	33	87	13	6±0.04	71±0.11

	Risk factors							
	Smoking (n)			Alcoholic beverages			Coffee (n)	
	Non-smokers	Past smokers	Current smokers	Non-drinkers	Drinkers of 1-9 glasses/ week	Drinkers of ≥ 10 glasses/ week	Non- and occasional drinkers	Regular drinkers
Peripheral arterial occlusive disease	13	21	66	15	9	76	15	85
Controls	45	19	36	30	17	53	58	42

* Mean ± standard error.

Source: Y. Skalkidis et al. (Int J Epidemiol 1989; 18:614-18).

TABLE 2

FREQUENCY DISTRIBUTIONS BY MARGINAL TERTILES AND MEAN VALUES OF DAILY CONSUMPTIONS OF ALL THE NUTRIENTS STUDIED, FOR 99 CASES OF PERIPHERAL ARTERIAL OCCLUSIVE DISEASE AND 98 COMPARISON PATIENTS*: ATHENS, GREECE, 1988

		Tertiles				
Variable	**Subjects**	**1 (low)**	**2**	**3 (high)**	**x** (p value)**	**Mean ± standard deviation**
Energy	Cases	29	35	35		2,100.9±427.5
	Controls	37	30	31	1.042 (0.30)	2,019.1±187.4
Total fat	Cases	29	31	39		109.4±24.8
	Controls	36	29	33	1.106 (0.27)	104.3±23.2
Saturated fat	Cases	29	31	39		45.1±11.5
	Controls	37	33	28	1.643 (0.10)	40.9±10.8
Monounsaturated fat	Cases	28	33	38		39.2±8.9
	Controls	38	32	28	1.736 (0.08)	37.3±7.4
Polyunsaturated fat	Cases	30	43	26		12.5±4.7
	Controls	35	21	42	-0.953 (0.34)	13.7±4.9
Total carbohydrates	Cases	34	35	30		173.4±43.8
	Controls	32	30	36	-0.695 (0.48)	178.6±40.7
Sucrose	Cases	34	30	35		35.5±19.8
	Controls	31	36	31	0.087 (0.93)	32.7±14.2
Crude fiber	Cases	37	36	26		7.3±2.1
	Controls	28	30	40	-2.005 (0.05)	8.3±2.3
Protein	Cases	21	35	43		113.6±22.1
	Controls	44	31	23	3.747 ($<10^{-3}$)	102.0±18.1
Cholesterol	Cases	17	34	48		634.8±161.5
	Controls	48	32	18	5.316 ($<10^{-6}$)	501.0±121.5
Vitamin C	Cases	40	34	25		123.6±43.4
	Controls	26	30	42	-2.682 (0.007)	137.6±42.7

* There are missing values for one case and two controls.
** x for linear trend and corresponding two-tailed p value.

of dietary composition (such as the health effect of 40 % calories from fat vs. 30 %) and is directly interpretable for dietary recommendations.

In all multivariate analyses, a core model was used in order to control for age, sex, years of schooling, smoking habits, regular alcohol and coffee intake, and Quetelet index (weight [Kg]/height [m]^2, since these variables are related to the risk of peripheral arterial occlusive disease and may also be independently related to dietary patterns. By contrast, some factors that are risk indicators for peripheral arterial occlusive disease (e.g., hypertension, diabetes, and, theoretically, hypercholesterolemia) were not adjusted for in the analysis, since they may be considered as representing intermediate steps in the causal link, if any, between diet and peripheral arterial occlusive disease[23].

Table 1 shows univariate characteristics of 100 patients with peripheral arterial occlusive disease and 100 comparison patients. There are clear differences in some of these variables that were all included in the core model in all subsequent analyses (unless otherwise indicated). Univariate frequency distributions of cases and controls by marginal tertiles of all the studied nutrients, as well as the mean + standard deviation of all nutrient measurements for cases and controls, are described in Table 2. Given the intercorrelations between the various nutrients, these data are not directly interpretable. Nevertheless, it is evident that total energy intake is not a major risk factor, that polyunsaturated fat and saturated fat have probably opposite effects, that crude fibre and vitamin C may be negatively related to the risk of peripheral arterial occlusive disease, and that protein and cholesterol intake are probably strong risk factors for this disease. Odds ratios of peripheral arterial occlusive disease contrasting the 75th centile with the 25th centile of the distribution of specific nutrient

TABLE 3
ODDS RATIOS (OR) OF PERIPHERAL ARTERIAL OCCLUSIVE DISEASE, ADJUSTED FOR ENERGY AND VARIOUS NONNUTRIENT RISK FACTORS*, CONTRASTING THE 75th WITH THE 25th CENTILE OF THE DISTRIBUTION OF SPECIFIC NUTRIENT RESIDUALS: ATHENS, GREECE, 1988

Variable	OR (75th vs. 25th centile)
Total fat	1.23 (0.71-2.14)**
Saturated fat	1.96 (1.14-3.39)
Monounsaturated fat	1.14 (0.68-1.91)
Polyunsaturated fat	0.48 (0.24-0.93)
Total carbohydrates	0.44 (0.23-0.82)
Sucrose	1.04 (0.61-1.78)
Crude fiber	0.33 (0.17-0.64)
Protein	2.86 (1.47-5.55)
Cholesterol	6.07 (2.74-13.46)
Vitamin C	0.34 (0.18-0.64)

* Sex, age (four 10-year group categories), years of schooling (continuous), smoking habits (four categories: nonsmokers, past smokers, current smokers of up to 1 pack per day, current smokers of more than 1 pack per day), alcohol intake (three categories: nondrinkers, drinkers of up to nine glasses per week, drinkers of 10 or more glasses per week), coffee drinking (non- and occasional drinkers, regular drinkers), and Quetelet's index (continuous).

** Numbers in parentheses, 95% confidence interval.

TABLE 4
ODDS RATIOS (OR) AND 95% CONFIDENCE INTERVALS (CI) OF PERIPHERAL ARTERIAL OCCLUSIVE DISEASE ASSOCIATED WITH AN INCREASE OF 1% IN THE ENERGY DENSITY OF SATURATED, MONOUNSATURATED, AND POLYUNSATURATED FATS (expressed as percentage of total energy)*: ATHENS, GREECE, 1988

Variable	OR	95% IC
Saturated fat	1.23	1.03-1.46
Monounsaturated fat	1.05	0.86-1.27
Polyunsaturated fat	0.73	0.56-0.96

* Adjusted for energy intake and for the variables sex, age, years of schooling, smoking habits, alcohol intake, coffee drinking, and Quetelet's index.

residuals, controlling for total caloric intake and other variables in the core model, are displayed in Table 3. For a given amount of total energy intake, saturated fat has a detrimental effect and polyunsaturated fat has a protective effect, whereas monounsaturated fat appears neutral with respect to the risk of peripheral arterial occlusive disease. Although the data in Table 2 for polyunsaturated fat suggested the possibility of a nonlinear relation, a quadratic term (polyunsaturated fat to the second power) was far from significant (*p*=0.39), indicating that the apparent nonlinearity was easily compatible with chance. Total carbohydrate intake appears protective, probably because of its substitution for saturated fat and possibly because of the protective effect of crude fibre. Protein intake and cholesterol intake are strong risk factors for peripheral arterial occlusive disease possibly, to a certain extent, because of confounding due to saturated fat. The variables indicated in Table 3 were introduced alternatively in the core model, which also included total energy intake; when saturated fat and cholesterol were simultaneously introduced in this model, their regression coefficients were slightly reduced but remained significantly different from the null value. The addition of terms for diabetes (entered as a 0, 1 variable, and a separate variable for fasting blood sugar among diabetics) did not appreciably alter the coefficients for saturated, monounsaturated, and polyunsaturated fats. Vitamin C and crude fibre were also inversely related to the risk of peripheral arterial occlusive disease. When these two nutrients were simultaneously introduced in a model including both saturated and polyunsaturated fat as well as the core variables, their regression coefficients became slightly closer to the null value but remained significantly different from it.

Table 4 shows odds ratios for peripheral arterial occlusive disease associated with an increase of 1 % in the energy density of saturated, monounsaturated and polyunsaturated fats (expressed as the percentage of total energy), adjusted for total energy intake and the core model factors. The results are qualitatively similar to those obtained when the residuals method was applied (Table 3). They indicate, again, that saturated fat has a detrimental effect for peripheral arterial occlusive disease and that polyunsaturated fat has a protective ef-

TABLE 5
MULTIPLE LOGISTIC REGRESSION-DERIVED ODDS RATIOS (OR) OF PERIPHERAL ARTERIAL OCCLUSIVE DISEASE AND 95% CONFIDENCE INTERVALS (CI) ASSOCIATED WITH A 100-kcal PER DAY INCREASSE OF INTAKE OF MAJOR ENERGY-GENERATING*: ATHENS, GREECE, 1988

Nutrient	OR	95% IC	p value (two tailed)
Saturated fat	1.37	0.60-3.17	0.46
Monounsaturated fat	1.06	0.36-3.18	0.92
Polyunsaturated fat	0.22	0.05-0.90	0.04
Total carbohydrates	0.63	0.43-0.92	0.02
Protein	3.70	1.30-10.51	0.01

*All odds ratios are adjusted mutually and for the core variables sex, years of schooling, smoking habits, alcohol intake, coffee drinking, and Quetelet's index.

fect, whereas monounsaturated fat appears neutral with respect to the risk of this disease. Interaction terms between any particular nutrient density and the corresponding nutrient were far from significant ($p=0.34$ for saturated fat, 0.22 for monounsaturated fat, and 0.75 for polyunsaturated fat), whereas interaction terms between any particular nutrient density and energy intake are the corresponding nutrients themselves.

Table 5 shows multiple logistic regression-derived odds ratios for peripheral arterial occlusive disease associated with a 100-kcal increase of the major energy-generating nutrients. These estimated odds ratios are adjusted both mutually and for the core variables previously indicated (and also shown in the footnote of Table 3). It should be noted that in this model total energy is not introduced as an independent variable to avoid overparameterization; in any case, total energy is not a significant or important risk factor in the present data.

Control of mutual confounding between major energy-generating nutrients has a modest effect on the estimated odds ratios. Thus, intake of total carbohydrates and polyunsaturated fats remains protective, intake of protein remains detrimental, and intake of monounsaturated fat remains neutral with respect to the risk of peripheral arterial occlusive disease; only intake of saturated fat becomes statistically nonsignificant while remaining a positive risk factor for the disease. In this model, the regression coefficients allow descriptive mutual comparisons. However, interval estimates of the differences between any two regression coefficients and associated statistical testing are not possible without using more elaborate procedures. In this and other models that included dietary variables, cigarette smoking and alcohol consumption remained significant predictors of peripheral arterial occlusive disease, indicating that their effects were not accounted for by differences in diet among smokers and alcohol drinkers.

This study has three shortcomings[16]: patients with peripheral arterial occlusive disease were not and could not be clearly definable «incident» cases; the case-control study was not population based in the traditional sense; and cholesterol values were not available for the comparison patients for practical reasons. However, the short-term fatality of peripheral arterial occlusive disease is low compared with the short-term fatality of coronary heart disease, where sudden death can introduce potentially serious selection bias in case-control studies; known or suspected selection factors for hospitalization (i.e., age, sex, socioeconomic status as reflected in years of schooling, cigarette smoking, and alcohol consumption) were accounted for in the analysis; and cholesterol, even if available, would not have been controlled in the analysis, since it represents a likely pathway in the causal link between diet and peripheral arterial occlusive disease. Nevertheless, the possibility of selection or recall bias cannot be completely eliminated in a study of this design; hence, the relations we found should be examined in other populations. On the positive side, the study was conducted with a food frequency questionnaire that has been used in numerous studies, and the analysis was undertaken taking into account new methodological developments[19, 21-23].

Results of the present study support the hypothesis that a diet high in saturated fatty acids, cholesterol and proteins increases the risk of atherosclerotic disease, whereas diet high in polyunsaturated fatty acids and dietary fibre reduces this risk; indeed, the associations appear compatible with those predicted on the basis of Keys equations[14]. Monounsaturated fatty acids in an isocaloric diet do not materially affect the risk of peripheral arterial occlusive disease, but if they are substituted for saturated fatty acids they should have a beneficial effect by eliminating the detrimental effects of saturated fats.

It is difficult to state whether proteins, dietary cholesterol and saturated fats have independent or converging effects, or even whether residual confounding is partly responsible for one or more of the relations noted in this study. It should be noted, however, that dietary cholesterol has been found to be atherogenic in humans even when serum total cholesterol is kept relatively constant in the analysis[24].

The apparent protective effect of vitamin C was found to be independent of its correlation with dietary fibre. Vitamin C and other antioxidants are hypothesized to protect the arterial endothelium from damage[25] and to inhibit the incorporation of cholesterol into macrophages in the arterial intima[26]. Vitamin C levels in blood were inversely related to the degree of coronary artery occlusion among patients evaluated by angiography[27].

Olive oil is defined as the oil obtained from the fruit of the olive tree (*Olea europaea Sativa*) to the exclusion of oil obtained by solvent or reesterification processes and any mixture with oils of other kinds[28]. According to the Recommended International Standard for Olive Oil, Virgin and Refined, the fatty acids composition (percentage (mol/mol) of methyl esters) is defined as follows: oleic acid (56.0-83.0), *palmitic* acid (7.5-20.0), *linoleic* acid (3.5-20.0), stearic acid (0.5-3.5), palmitoleic acid (0.3-3.5), linolenic acid (0.0-1.5), myristic acid (0.0-0.05) and other fatty acids in minute amounts. Olive oil represents an important component of the

Greek diet[20] and, more generally, of the Mediterranean diet. The results of the present study indicate that olive oil, the primary source of monounsaturated fat, occupies an intermediate position between polyunsaturated and saturated fats in relation to peripheral atherosclerosis. To the extent, however, that olive oil substitutes for saturated fats in food, a diet rich in olive oil should be healthier than a diet rich in saturated fats. A diet rich in polyunsaturated fat should be best in this context, but there is growing concern that habitual intake of large quantities of polyunsaturates may not be healthy, since they promote carcinogenesis in experimental animals and may have other undesirable health effects[29]. By contrast, the Mediterranean diet and, in particular, the traditional Greek diet have existed for a very long time and been associated with some of the lowest overall mortality patterns observed in large human populations[15]. Our findings provide evidence that the traditional Mediterranean diet contributes to the low rates of cardiovascular disease in southern Europe and support the hypothesis that diets high in animal products containing substantial amounts of saturated fat and cholesterol are partly responsible for the high rates of atherosclerotic disease in Western populations.

MONO-ENE FATTY ACIDS IN THE PREVENTION OF DYSLIPOPROTEINEMIA AND ATHEROSCLEROSIS

RAFAEL CARMENA

Studies conducted over 20 years ago by Keys, Anderson and Grande[1,2] and by Hegsted et al.[3] demonstrated that the effect of dietary fat on plasma cholesterol levels in man depends on the fatty acid composition of the fat: saturated fatty acid glycerides (SFA) cause an increase in total serum cholesterol, whereas polyunsaturated fatty acids (PFA) cause a decrease. The effects of mono-ene fatty acids (MFA) on total plasma cholesterol were considered neutral, not different from the effects observed with dietary carbohydrates. i.e. neither raising nor lowering total cholesterol levels. On the other hand, isocaloric substitution of MFA for saturated fat did lower serum cholesterol due to the removal of the cholesterol-raising effect of saturated fatty acids. Keys et al.[1] also reported that gram for gram, saturated fat is up to two times greater at raising serum cholesterol than are polyunsaturated fats in depressing it; thus, replacing dietary saturated fat with linoleic acid caused a larger decline in total cholesterol levels than MFA, carbohydrates or proteins. Based on these findings, a minimum of 10% of the energy uptake of the diet usually recommended[4,5] for lowering cholesterol is derived from PFA.

This whole concept, however, has begun to break down as the effects of MFA on serum lipids and lipoproteins have been rexamined. Several studies have emphasized the value of MFA-rich diets as a way of reducing saturated fat intake and lowering low density lipoprotein (LDL) cholesterol levels. Grundy[6] has shown that diets rich in MFA (oleic acid, c18:1 n-9) cause a reduction in LDL-cholesterol levels as low-fat high-carbohydrate diets do, but without lowering high density lipoprotein (HDL) cholesterol or raising serum triglyceride values. Also, in the past decade, some investigators have reported that increasing the intake of dietary linoleic acid (c18:2 n-6) led to decreases in HDL-cholesterol[7] but this did not occur if oleic acid-rich diets were used[8,9]. However, the quantity of total fat and the study conditions varied considerably, making it difficult to interpret the data.

From a different perspective, recent studies in experimental animals[10] show that diets enriched in oleic acid generate LDL particles that are highly resistant to oxidative modifications and could slow the progression of atherosclerosis.

In this paper we intend to review and discuss the present role of dietary mono-ene fatty acids in the prevention of dyslipoproteinemia and atherosclerosis.

DIETARY MONO-ENE FATTY ACIDS (MFA) AND SERUM LIPOPROTEINS.

Elevated LDL-cholesterol and decreased HDL-cholesterol levels have been independently associated with an increased risk of premature coronary heart disease (CHD) in man[11]. There is almost unanimous agreement that the concentration of LDL in serum decreases if SFA in the diet are replaced by PFA. As previously indicated, several studies have also shown that HDL levels are lowered by diet rich in PFA[7,8,9].

Since HDL may protect against CHD, diets chosen for lowering total serum cholesterol should not lower HDL. Results from the Seven Countries Study[12] have shown that the Cretan diet combined a low intake of SFA with a high intake of fat because of their liberal use of MFA in the form of olive oil. The incidence of CHD in Cretan men was lower than would be expected from their total fat consumption and serum cholesterol levels, and this could not be explained by other risk factors for CHD. HDL-cholesterol levels, however, were not studied and the possibility that dietary replacement of saturated by monounsaturated fatty acids could lower total serum cholesterol levels, while leaving HDL levels unchanged, has recently been examined by different investigators.

Schlierf et al.[13] were among the first to study the effects of a PFA rich (corn oil) diet and an olive oil rich diet on

HDL-cholesterol levels in man. A 17% decrease in LDL cholesterol was seen when comparing the control and the olive oil diet, and HDL cholesterol fell during the olive and corn oil periods, leaving the Apo AI and AII unchanged.

Mattson and Grundy[8] compared MFA (oleic) and PFA (linoleic) acids when substituted for saturated (palmitic) acids, administered in liquid formula diets, for their effects on serum lipoproteins. The two unsaturated fatty acids had almost identical effectiveness in reducing total serum cholesterol and LDL cholesterol. High intake of linoleic acid did lower HDL cholesterol, while this response occurred less often when the patients were taking large quantities of oleic acid. In another study, Grundy[6] demonstrated that a liquid diet rich in MFA lowered serum total and LDL cholesterol to the same extent as a low-fat high carbohydrate diet. Serum HDL cholesterol levels were reduced during the low fat diet but did not change during the high MFA period.

These experiments have been criticized because formula diets were employed and a mixed group of healthy volunteers and hyperlipidemic patients was investigated. However, Mensink and Katan[14] obtained similar results in healthy volunteers when comparing the effects on serum lipids of a natural diet rich in olive oil with a diet rich in complex carbohydrates and low in fat. The olive oil-rich diet, which combined a high intake of total fat with a low intake of saturated fat, caused a specific fall in non-HDL cholesterol, leaving HDL-cholesterol unchanged. The complex carbohydrate-rich diet caused a decrease in total and HDL cholesterol. In a more recent experiment, the same authors[15] have used smaller amounts (less than 13% of total energy intake) of PFA and were unable to find differences between the mono-and polyunsaturated fat-rich diets; both lowered the level of LDL cholesterol and had the same effect on the HDL cholesterol.

This last point is of particular importance since a number of laboratories had suggested that dietary PFA lowered serum HDL cholesterol. In many of these studies very large amounts of linoleic acid in the diet were used. In the report by Mensink and Katan[15] the amount of linoleic acid used in the diet was close to what is consumed by the general population. Along the same lines, Iacono et al.[16] have recently shown that a diet containing either 3.8 or 10.8% in linoleic acid did not reduce serum HDL cholesterol values. A significant aspect of the study was that the quantity of SFA and MFA were kept constant.

Jacotot et al.[17] have reported that the consumption by healthy subjects of natural diets containing 40 g/day of olive oil – which is the amount usually consumed in Crete, according to Keys[12] – is associated with an increase in HDL-cholesterol level, an increase in LDL catabolism by cultured fibroblasts and an accelerated removal of cellular free cholesterol by HDL.

TABLE 1

	Males (N = 66)			Females (N = 43)		
	S.F.O.	O.O		S.F.O.	O.O	
TC	186+38	201+37	p. 0.005	212+56	227+52	NS
LDL-C	118+37	123+36	NS	118+46	116+44	NS
HDL-C	47+11	55+12	p. 0.001	61+13	76+14	p. 0.01
TG	83+38	79+36	NS	72+27	65+17	NS
A.I.	4.1+1.1	3.8+1.3	p. 0.001	3.6+1.1	3.3+0.9	p. 0.001

Notes: O.O.: Olive Oil period; S.F.O.: sunflower oil period; TC: total cholesterol; TG: triglycerides; A.I.: Atherogenic Index (TC/HDL-C).

Values are in mg/dl. To convert to mmol/1 multiply by 0.025 for cholesterol and 0.01 for triglycerides.

In a cooperative study conducted simultaneously in closed religious communities in Valencia and Madrid we compared the effects of natural diets containing 40 g/day of either olive oil or sunflower seed oil on serum lipoproteins and apoproteins. A detailed account of the study has been published[18]. In the male group, 43% of daily energy was derived from carbohydrates, 37% from fat, 16% from protein and 4% from alcohol, with a daily intake of 400 mg cholesterol and 25 g fibre. In the female group, the respective percentages were 48, 38 and 14%, respectively. Each dietary period lasted 3 months.

Part of the results are summarized in above. Table 1 This shows that, in males total cholesterol levels during the olive oil period were significantly higher than in the sunflower oil period. In the female group, mean total cholesterol during the olive oil period was 15 mg higher than during the sunflower oil period but this difference was not statistically significant. The HDL-C levels were significantly higher during the olive oil period in both groups, increasing by 17% in males and by 24% in females. The LDL-C levels did not differ significantly in any group when subjects changed from sunflower to olive oil. Thus, the rise in total cholesterol observed in both groups when consuming olive oil could be explained by the increase in the HDL-C fraction.

Serum triglyceride levels did not vary significantly when subjects changed from sunflower to olive oil. The atherogenic index (TC/HDL-C) fell by 7% in the males and by 8% in the female group during the olive oil period, reaching statistical significance.

In conclusion, at the amounts used in our study (14% of daily caloric content in the male group and 18% in females), isocaloric substitution of PFA (sunflower seed oil) for MFA (olive oil) was accompanied by a significant increase in HDL-cholesterol in both groups. We observed no differences in LDL-cholesterol levels between the dietary period rich in olive oil or in sunflower seed oil.

Recently, a study comparing the AHA step-one diet and a monounsaturated rich fat diet has been published[19]. The AHA step diet was enriched (18% of daily calories) with MFA (38% total calories from fat: 18% MFA, 10% SFA and 10% PFA) and was compared with the regular AHA step diet (30% total calories from fat, at 10% of each type). Both groups of patients showed parallel reductions in serum LDL-cholesterol and neither the triglyceride levels nor the HDL cholesterol concentrations changed significantly with any diet. The authors concluded that enrichment of the step/diet with monounsaturated fat does not alter the beneficial effects of the step/diet on serum lipid concentrations.

CIS VERSUS TRANS CONFIGURATION OF MONO-ENE FATTY ACIDS.

Hydrogenation (adding hydrogen atoms to double bonds) of vegetable oils rich in linoleic acid produce mono-ene fatty acids (oleic acid and elaidic acid) and stearic acid, an SFA that has no double bonds. Oleic acid, the principal naturally occurring-MFA, has one double bond of the *cis* configuration, i.e. the two hydrogen atoms attached to the double bond lie on the same side. Elaidic acid, on the other hand, is *trans* c18:1 (the hydrogen atoms lie on opposite sides of the double bond) and is a rigid molecule whose structure is similar to that of a saturated fatty acid[21].

In a recent report Mensink and Katan[21] have shown that diets enriched in elaidic acid were hypercholesterolemic as compared with oleic acid-rich diets. The effect of *trans* fatty acids on the serum lipoprotein risk profile was at least as unfavorable as that of the cholesterol-raising SFA, because they not only raised LDL-cholesterol but also lowered HDL-cholesterol levels.

These findings are not in agreement with previously conducted studies by Anderson et al.[22] and by Mattson et al.[23]. A 1985 report from the FASEB quoted by Reeves[24] reviewing the health effects of dietary *trans* fatty acids concluded that «the *trans* fatty acids consumed in hydrogenated vegetable oil appear to be the equivalent of oleic acid in their cholesterolemic properties in humans». As has been suggested, the study of Mensink and Katan provides evidence that a diet rich in elaidic acid raises LDL-cholesterol and reduces HDL-cholesterol, but it should be interpreted with caution[24]. The level of trans fatty acids used by these authors was about four times higher than that considered typical of a Western diet. As pointed out by Grundy[20], since trans fatty acids constitute only 3 percent of total energy intake in the American diet, are these findings of any practical importance?.

Although more investigations are needed, for the time being it would seem prudent for patients at risk of atherosclerosis to avoid a high intake of *trans* fatty acids.

OXIDATION OF LIPOPROTEINS AND DIETARY MONO-ENE FATTY ACIDS.

It has been reported that oxidative modification of LDL converts it to a more atherogenic form and that these changes can occur *in vivo*[25]. The susceptibility of LDL to oxidation appears to depend on the abundance of polyunsaturated fatty acids in the particle; during oxidation, the concentrations of linoleic and arachidonic (C20:4) acids decrease and several aldehyde species become detectable, yielding a lipid-protein conjugation which seems crucial for the recognition of the particle by the acetyl LDL receptor[27]. Oxidized LDL show an increased susceptibility to uptake by cultured macrophages, that are then converted into foam cells, the typical cells of the fatty streak.

Parthasarathy et al.[10] performing *in vivo* studies in the rabbit have shown that inhibition of LDL oxidation slows the progression of atherosclerotic lesions. Rabbits were fed either Trisun 80 (a variant of sunflower oil containing more than 80% oleic acid and only 8% linoleic acid) or conventional sunflower oil, containing only 20% oleic acid and 67% linoleic acid. LDL isolated from the plasma of animals fed Trisun 80 were higly enriched in oleic acid and remarkably resistant to oxidative modifications.

Recent results from a study on the action of MFA on plasma lipoproteins in a free living population conducted in Israel[28] show that during the dietary periods enriched in oleic acid the LDL particles were less susceptible to oxidative stress, while PFA-rich diets resulted in higher lipid peroxidation.

In conclusion, reducing the PFA content of LDL and increasing the MFA content seems to reduce the susceptibility of these particles to oxidation. Whether diets enriched in oleic acid may slow the progression of atherosclerosis by generating LDL resistant to oxidative modification awaits further studies.

REGULATION OF THE CONCENTRATION AND DISTRIBUTION OF LIPIDS IN BLOOD PLASMA

RONALD MENSINK

In the duodenum dietary triglycerides are reduced to small particles to make digestion possible with the help of bile salts, and of small quantities of fatty acids and monoglycerides. The pancreatic lipase enzyme is then able to hydrolyse dietary triglycerides into mono- and diglycerides, fatty acids and glycerol. The so-formed emulsion of lipids can pass the mucous membrane of the cells of the intestine. Within the cell further hydrolysis takes place and new triglycerides are formed by re-esterification of the fatty acids with glycerol. The lipids enter the lymph in chylomicrons and lastly the blood stream.

Triglycerides, and fat-soluble substances like cholesterol and phospholipids, are insoluble in water. To facilitate transport the majority of lipids in the blood are encapsulated by water-soluble proteins, the apoproteins. These complexes are called lipoproteins which consist of a hydrophobic core and a hydrophilic shield.

Many different lipoproteins can be found. In healthy subjects the triglyceride-rich chylomicrons are only present after a meal. Other important lipoproteins are the very-low density lipoproteins (VLDL), the low-density lipoproteins (LDL) and the high-density (HDL). VLDL, which is mainly secreted by the liver, is also rich in triglycerides. LDL and HDL, however, transport most of the cholesterol through the blood: LDL carries about 60-70 % percent of cholesterol and HDL 20-30 %. LDL can be from VLDL, and HDL from chylomicron remnants, but native vesicles are probably also secreted by the liver.

Many large-scale studies have shown that the risk for coronary heart disease is positively related to LDL cholesterol levels, but negatively to that of HDL cholesterol. In addition, high triglyceride level may also be associated with coronary heart disease. As lipoprotein cholesterol and triglyceride levels can be changed by dietary means, a prudent diet is important for lowering the risk of coronary heart disease.

Fats are an important determinant of serum lipid and lipoprotein cholesterol levels. A fatty acid is hypercholesterolemic when the serum total cholesterol increases, when carbohydrates in the diet are replaced by an isocaloric amount of this particular fatty acid.

Diet contains three different classes of fatty acids: saturated fatty acids have no double bonds, monounsaturated fatty acids have one double blond and polyunsaturated fatty acids have at least two double bonds.

EFFECTS OF DIETARY FATTY ACIDS ON SERUM TOTAL AND LDL CHOLESTEROL

Saturated fatty acids increase the serum total and LDL cholesterol levels. Lauric, myristic and palmitic acid - saturated fatty acids with 12, 14 and 16 carbon atoms - will elevate the serum total and LDL cholesterol level when compared with isocaloric amounts of carbohydrates. Saturated fatty acids with less than 12 carbon atoms or with 18 carbon atoms – stearic acid – do not influence the serum cholesterol level.

The two major unsaturated fatty acids in the diet are oleic acid and linoleic acid. According to studies carried out in the fifties and sixties by the groups of professor Keys and of professor Hegsted, linoleic acid is superior to oleic acid for lowering serum total cholesterol levels.

Several recent studies, however, could not confirm these findings: oleic and linoleic acid were found to be equally hypocholesterolemic. Recently, a meta-analysis of 27 trials was published that suggested that linoleic acid may be marginally more hypocholesterolemic than oleic acid. The difference between these two unsaturated fatty acids, however, was much less than that in the earlier studies. Individual studies suggest that the oleic acid and linoleic acid can be exchanged without any effect on serum total and LDL cholesterol levels as long as the intake of linoleic is within the normal range.

EFFECTS OF DIET ON SERUM HDL CHOLESTEROL

It has been suggested that part of the cholesterol lowering effect of linoleic acid consists of lowering the level of HDL cholesterol. Indeed, many studies have shown that at high intakes linoleic acid lowers HDL cholesterol levels relative to saturated and monounsaturated fatty acids. Substituing oleic acid in the diet for carbohydrates also increases HDL cholesterol.

EFFECTS OF DIET ON SERUM TRIGLYCERIDE LEVELS

Replacing carbohydrates in the diet by olive oil will lower serum triglycerides. Oleic acid and linoleic acid, however, have similar effects on the serum triglyceride level.

ARTERIOSCLEROSIS: FAT OXIDATION AND CORONARY HEART DISEASE

Polyunsaturated fatty acids are more readily oxidized than monounsaturated fatty acids. Oxidation not only happens during the processing of oils, but also inside the human body. It has been proposed that oxidized LDL is highly atherogenic. Native LDL passes the endothelial cells and can then be oxidized within the artery. Oxidized LDL is readily taken up by macrophages, which leads to foam cells and finally to the fatty streak. In addition, modified LDL also has chemotactic activity and cytotoxic properties, which all enhance the rate of fatty-streak formation.

Despite experimental evidence from animal studies of a role of lipid peroxidation in the pathogenesis of atherosclerosis, information from human studies was scarce. Recent studies, however, have shown a positive relationship between autoantibodies against modified LDL and the progression of carotid atherosclerosis. Another study found that the severity of coronary atherosclerosis is positively associated to susceptibility to LDL oxidation in an in vitro system.

The fatty acid composition of the LDL particle is largely determined by the fatty acid composition of the diet. Thus diets high in linoleic acid give rise to high levels of linoleic acid in the cholesterylester moiety of the LDL, and oleic-acid-rich diets to high levels of oleic acid.

It is therefore not surprising that LDL particles from subjects on a high linoleic acid diet are more prone to oxidation than LDL particles from subjects on a high oleic acid diet. In addition, it was found that degradation of LDL by mouse macrophages after modification by endothelial cell from rabbits was much more pronounced on linoleic-acid diet as compared with an oleic-acid diet.

NUTRITION AND FRIED FOODS

GREGORIO VARELA

There is one very important factor regarding fat intake in Spain and in the Mediterranean countries in general that is rarely taken into account, namely, the high proportion of the total that is 'culinary fat'. The fat we consume consists of two basic ingredients, namely, the fat contained in foods and the culinary fats and oils used to prepare food. In Spain and in the Mediterranean countries about half of the total fat intake is in the form of culinary fat. This is an advantage since it offers greater scope for controlling fat intake than in countries where the proportion of cooking fat is much smaller.

This gives rise to a question. How is this cooking fat consumed? We have devoted a considerable proportion of our studies to attempting to answer this question. In principle, it should be remembered that only a small proportion of such fat is consumed uncooked in the form of dressings while the major proportion is used basically in deep frying.

This cooking technique originated in the Mediterranean countries and is one of the few characteristics common to all of them although until recently it did not enjoy a particularly good press. However, on account of the studies carried out in various laboratories, among them our own, ideas on the subject have changed drastically and this method of cooking is today becoming increasingly popular in countries where it was hitherto unusual and it is now being used for a wide variety of foods.

This expansion is due, to a large extent, to greater knowledge about how fat penetrates fried foods. It has been demonstrated that when frying is carried out correctly, at the right temperature and for the right length of time, with the right proportions between the food surface and volume and the cooking fat, a crust forms on the surface of the food which prevents the hot oil from penetrating the food itself. Olive oil has been found to be particularly suitable for such deep frying.

It is difficult to summarise the practical benefits of this method of cooking but, generally speaking, it can be said that, on account of this outer crust around the food, the time which the hot oil has to act on the core of the food is very limited so the loss of nutritional value in the case of fried foods is much smaller than with other methods of cooking. The same can be said as regards the quantity of fat actually consumed when compared with other methods of cooking.

However, perhaps the most important fact with regard to frying is that it enables us to adjust fat intake.

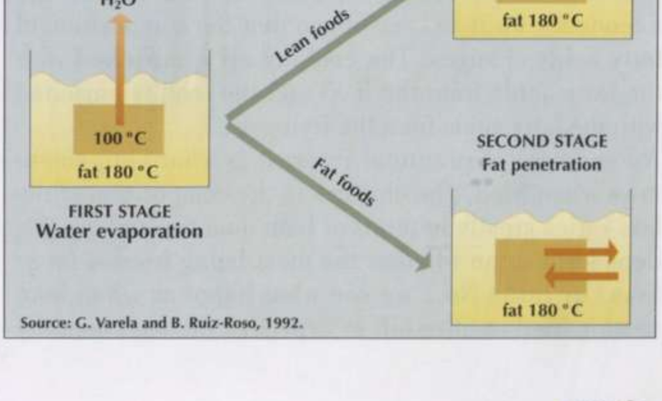
With regard to the actual penetration of the oil into the food, it is interesting to note that this varies depending upon whether the food fried is fat or lean. In Graph No.1 we have endeavoured to describe the process of penetration by the oil of the two types of food. In both cases, what happens is that firstly, before the food is penetrated by the hot oil, a considerable amount of water evaporates and leaves the food, during which time the temperature within the food remains practically constant at 100ºC.

Once the water has evaporated, the hot fat starts to penetrate the food and, as can be seen from the graph, this varies a great deal depending upon whether the food is fat or lean. If it is lean, the oil will penetrate the food which is enriched. The composition of the fat in the fried food will be practically the same as that of the cooking oil.

The problem is much more complex in the case of fatty foods. From the quantitative point of view, the amount

FIGURE 1

FAT PENETRATION IN FOODS IN DEEP FRYING



Source: G. Varela and B. Ruiz-Roso, 1992.

TABLE 1
CHANGES IN FAT COMPOSITION DUE TO FRYING

	Lean Food		Fatty Food		
	Potatoes		Sardines		
	Raw	Fried OO	Raw	Fried OO	Fried SFO
Total fat	0.16	16.5[a]	20.2	20.3	20.2
SFA	23.1	13.2[a]	42.4	30.6[a]	26.4[a]
MUFA	3.1	78.2[a]	29.5	46.0[a]	32.8
PUFA (total)	73.1	8.4[a]	26.6	23.1	33.6[a]
n-6			4.9	6.6	26.2[a]
n-3			21.3	16.5	7.0[a]

Total fat is expressed as g/100 g of food and fatty acid families are expressed in g/100 g of fat; OO: olive oil; SFO: sunflower oil;
[a] Significant when compared to raw ($p<.05$).
Source: G. Varela, M. Pérez and B. Ruiz-Roso, 1990.

TABLE 2
CHANGES IN LIPID COMPOSITION OF LEAN AND FATTY BEEF FRIED IN OLIVE OIL

	OO	Beef			
		Lean		Fat	
	Raw	Raw	First Frying	Raw	First Frying
Total fat (g/100 g food)	100	3.1	6.4[a]	41.0	40.8
SFA	15.7	41.2	28.6[a]	43.8	42.0[a]
MUFA	74.4	43.2	61.5[a]	49.5	52.0[a]
PUFA (g/100 g total fat)	9.7	16.6	9.6[a]	2.3	2.0[a]

Total fat is expressed as g/100 g of food and fatty acid groups are expressed in g/100 g of fat; OO: Olive oil;
[a] Significant when compared to raw ($p<.05$).
Source: G. Varela and B. Ruiz-Roso, 1992.

of fat passing from the food to the frying oil and vice versa is practically the same, so there are no major changes with regard to the total quantity of fat in the food. However, there are qualitative differences that depend largely upon the varying concentrations of the different fatty acids in the cooking oil and in the food. In very general terms and without going into detail, it can be said that when the concentration of a given component is greater in one medium than in the other, there is a tendency for it to even out so that the composition of fatty acids changes. The cooking oil is enriched with the fatty acids from the food and the food is enriched with the fatty acids from the frying oil.

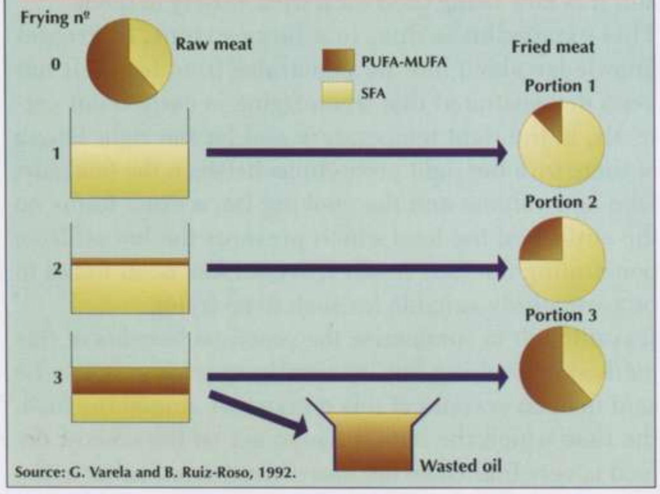
An example of practical interest is what happens to meat when fried. The changes in the composition of the fats varies greatly in terms of both quantity and quality, depending upon whether the meat being fried is fat or lean. In Table No.1 we see what happens when lean meat is fried in olive oil: as expected, the total quantity of fat increases. As far as quality is concerned, the proportion of saturated fatty acids (SFA) in the meat drops noticeably, while the monounsaturated fatty acids (MUFA) increase and the polyunsaturated fatty acids (PUFA) decrease.

In the case of fat meat, the quantitative changes are not significant. In practical terms, the amount of fat that leaves is the same as that which enters while the changes to the families of fatty acids are in line with the concentration gradients. The SFA decrease, the MUFA increase and there is no change in the PUFA since the concentration of these in the meat and the oil is very similar.

At this stage, it should be considered whether the fat would have the same effect if ingested separately rather than in the meat. This is not the case, as research in our laboratory has shown. It must be remembered that, when food is fried, the same oil is used not once but a number of times to fry fresh portions of food. However, after repeated frying, the used oil has to be discarded so is not ingested.

The quantity of discarded oil may be quite large and will depend on the composition of the fat and of the food fried in it and on the stability of the cooking oil used, so this may be of practical importance in terms of actual fat intake. It is difficult to estimate the quantity of oil discarded, but it is generally calculated as being at least 20%. However, it is very important to bear in mind that the composition of the oil thrown away is not the same as that of uncooked oil. If used for frying meat, it will have added saturated fatty acids. In practical terms, this means that total fat intake is reduced and that negative compounds are discarded along with the used oil. At the same time, the fat con-

FIGURE 2
QUANTITY AND QUALITY OF THE FAT INTAKE IN REPEATED MEAT FRYING



Source: G. Varela and B. Ruiz-Roso, 1992.

tent of the meat improves considerably because it is penetrated by monounsaturated and polyunsaturated fatty acids.

Figure 2 shows the changes which occur in olive oil after repeated frying of fat meat. With successive frying of portions of meat having approximately the same fat composition, the SFA content of the oil slowly increases. But when the oil has been used 20 times, the increase stops and the concentration of SFAs evens out. This shows that in repeated frying the oil receives SFAs until, when there is practically no difference between the food and the oil, the oil composition becomes stable. For the same reason, there is a marked drop in MUFA and a more gradual drop in PUFA.

The conclusion is that it is difficult, in general terms, to relate fat intake to degenerative diseases and that frying techniques, if properly used, facilitate the control of fat intake.

THE USE OF OLIVE OIL IN THE DIABETIC DIET

ABHIMANYU GARG

Dietary therapy is the cornerstone of the management of patients with diabetes mellitus. The aim of diet is to normalize the various derangements in intermediary metabolism in patients with diabetes mellitus, most importantly, hyperglycemia and hyperlipidemias. Another important objective of diet therapy is to prevent long-term complications of diabetes, particularly coronary heart disease (CHD).

Diet may be the sole therapy in some patients with non-insulin-dependent diabetes mellitus (NIDDM or type II diabetes mellitus), whereas others may require oral hypoglycemic drugs or insulin in addition. Diet therapy also plays an important role in the management of patients with insulin-dependent diabetes mellitus (IDDM or type I diabetes mellitus) and patients belonging to other categories of diabetes mellitus; however, insulin or other drugs may be essential in the overall management.

The currently prescribed diets to patients with diabetes mellitus are low in saturated fatty acids and cholesterol and rich in carbohydrates and fibre[1]. Saturated fatty acids are restricted to less than 10% of total daily energy intake and more than 55-60% of total energy is derived from carbohydrates. In diabetic patients with hyperlipidemias, a further increase in dietary carbohydrates and restriction of fats to 20% of total energy is advised. In spite of these recommendations, there is no consensus about the optimal diet for diabetic patients[2].

Recently, Garg et al.[3] proposed an alternative approach to diet therapy in patients with diabetes mellitus - the replacement of complex carbohydrates with monounsaturated fats using olive oil as the source of monounsaturated fatty acids. The study revealed that compared to a high carbohydrate, low saturated fat diet, a diet rich in monounsaturated fats but low in saturated fats improved glycemic control and lipoprotein profile in NIDDM patients on insulin therapy. The insulin requirements of the patients were lower and plasma glucose profile was much improved on the highmonounsaturated fat diet. Furthermore, compared to the high carbohydrate diet, the high monounsaturated fat diet reduced fasting plasma triglyceride levels by 25% and very low density lipoprotein (VLDL) cholesterol levels by 35%, and raised concentrations of HDL-cholesterol and apolipoprotein A-I by 13% and 9%, respectively. Thus, overall results revealed that a high monounsaturated fat diet may improve the coronary risk profile of patients with NIDDM.

In another recent study, Garg and co-workers[4] using the euglycemic, hyperinsulinemic, glucose clamp technique found no evidence to support the previous contention that high carbohydrate diets improve glycemic control or insulin sensitivity in patients with mild NIDDM. In a separate investigation, Garg et al.[5] showed that high carbohydrate diet induced hyperglycemia in NIDDM patients which was accompanied by hyperglucagonemia, and in some patients with beta cell dysfunction. In contrast, a diet rich in monounsaturated fatty acids had no adverse effects on glycemic control and islet cell functions in NIDDM patients[5]. Other investigators[6-8] have confirmed the beneficial effects of monounsaturated fatty acid rich diets in NIDDM patients and results of a recent multicentre study[9] also support the use of high monounsaturated fat diet in NIDDM patients.

The diets rich in monounsaturated fatty acids therefore may be particularly useful in patients who are not compliant to high carbohydrate diets. The high monounsaturated fat diets with olive oil may be more palatable. Usually elderly patients with NIDDM will not readily change their dietary habits and therefore an exchange of monounsaturated fatty acids for saturated fatty acids may be better accepted than the replacement of saturated fatty acids with carbohydrates. Because of adverse effects of high carbohydrate diets on lipoproteins, high monounsaturated fat diets may be prescribed to those patients who have hypertriglyceridemia and low levels of HDL cholesterol and those who have difficulty in managing hyperglycemia.

The same dietary approach may also be used for IDDM patients. In fact, in a short-term study of IDDM patients[10], compared to the usual high carbohydrate diet, a high monounsaturated fat diet improved glycemic control, but the lipoprotein profile remained unchanged. Thus, a diet rich in monounsaturated fatty acids may be a suitable alternative to a high carbohydrate diet for IDDM patients also, particularly for those with hypertriglyceridemia and low HDL cholesterol levels, and for pregnant patients. In fact, the recent dietary recommendations of the American Diabetes Association[11] include individualization of the dietary advice for patients with diabetes mellitus and patients are allowed to choose between a high carbohydrate diet or a high monounsaturated fat diet.

ALIMENTARY LIPIDS AND AGEING

Publio Viola
Mirella Audisio

The biological limit of life appears to be determined by numerous genetic and environmental factors including eating habits. The numerous theories put forth to explain the ageing process include in particular: 1) the *immunological theory*, which considers the progressive consumption of the immunity system to be the cause of the incapacity of the organism to defend itself against external aggression; 2) the *theory of errors*[1], according to which every organism inherits information containing a 'programme' that organises its biological activity and which theoretically can be repeated in an unlimited manner; in the course of this repetition of the programme, incidental errors occur which may, in turn, cause other errors until a «catastrophe of errors» is reached; 3) the *theory of peroxidation by free radicals*[2], highly reactive chemical substances which form during the metabolic reactions and cause damage to the cell structures, thereby inducing both the typical alterations of ageing and the illnesses related to that process.

Recent studies have yielded new elements in support of this theory and have pointed to cell damage as a consequence of the action of the free radicals of oxygen.

LIPID PEROXIDATION AND FORMATION OF FREE RADICALS

In our organism, reactions occur continuously and ubiquitously, which contribute to the formation of free radicals; however, they usually cause no serious damage, because we are protected by anti-oxidising substances which (within certain limits) maintain an equilibrium.

This equilibrium can be upset by a decrease in the anti-oxidising substances, by the increase of pro-oxidising substances or by an increase of the peroxidisable substrate. Such alteration leads to «oxidative stress» which can be defined as a condition where exposure to free radicals or to other oxidisers creates an element of disturbance for the normal functioning of the cell or even for its very survival.

The anti-oxidising agents are represented by α-tocopherol, ß-carotene, ascorbic acid, uric acid, superoxidodismutase, glutathione peroxidase, catalase, cerulplasmine, α-1-antitripsine and certain amino acids such as methionine and cysteine. Other substances like polyphenols, the activity of which has been ascertained *in vitro* although not yet *in vivo*, cannot be excluded. The pro-oxidising agents comprise free radicals, which may be induced by polluting substances, tobacco smoke, certain xenobiotic substances or certain metals such as iron and copper, by intense metabolic activity and even by atmospheric oxygen.

Particular importance is attributed to oxygen, in that its metabolic utilisation occurs at the mitochondrial respiratory chain where, however, 2-5% is not completely reduced to water, but forms intermediate, highly reactive products, such as the free radicals superoxide ($0^{-}\bullet$) and hydroxyl (OH^{+}).

$$O_2 \xrightarrow{e-} O_2^{-}\bullet \xrightarrow{e- + 2H^+} H_2O_2 \xrightarrow[H_2O]{e- + H^+} OH^+ \xrightarrow{e- + H^+} H_2O$$

Free radicals are also formed during the synthesis of prostaglandins, in the course of inflammatory processes and at the transport chain for the microsomal NADPH cytochrome P 450 electrons.

Once they have formed, the free radicals react and tend to stabilise by the removal of one hydrogen atom from another substrate. The repetition and propagation of the cycle thus occurs with a radical chain reaction. A particular lability to cede hydrogen atoms is characteristic

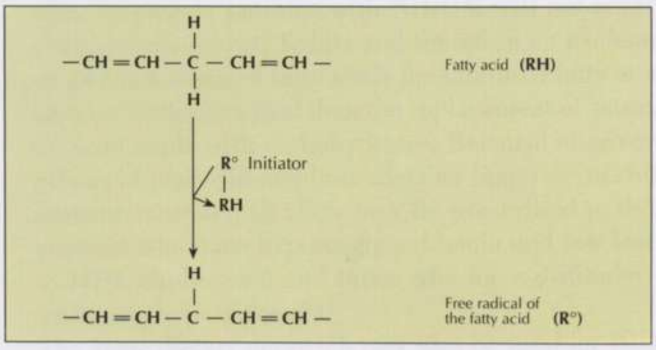


FIGURE 1. Initiation of the process of formation of free radicals from a polyunsaturated fatty acid.

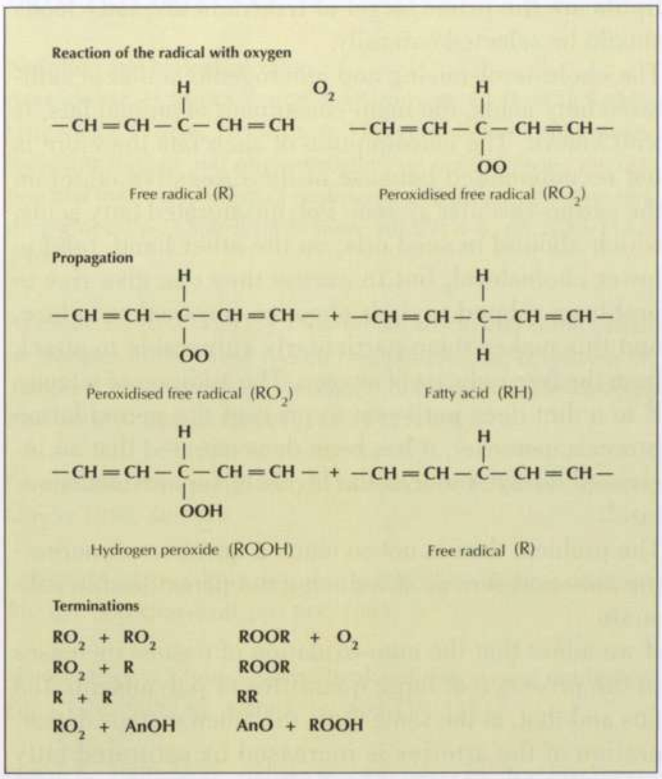


FIGURE 2. Propagation of the process of formation of radicals and terminations due to the action of an antioxidant.

of poly-unsaturated fatty acids, which in turn, can be transformed into free radicals (Figures 1 and 2).

The free radicals of the fatty acids can therefore react with the molecular oxygen to form the peroxidised free radicals (ROO) which, through a chain reaction, can then propagate the process to other poly-unsaturated fatty acids and give rise to new free radicals (R), hydroperoxides (ROOH) and breakdown products such as malonyldialdehyde.

Due to their divinylmethane type of structure, poly-unsaturated fatty acids are less stable at the level of methylene groups situated between non-adjacent double bonds (non-conjugated dienes), which promotes the triggering of the release of radicals. This process is actually null or negligible for the saturated fatty acids, relatively slow for mono-unsaturated fatty acids, and increasingly fast depending on the number of double bonds present in a poly-unsaturated chain fatty acid. In fact, the peroxidation speed from saturates to mono-unsaturates, to di-unsaturates, tri-unsaturates and tetra-unsaturates increases in a proportion of o:0.025:1:2:4. Arachidic acid (20:4 *w* 6) is thers 160 times more susceptible to peroxidation than oleic acid (18:1 *w* 9).

Our aerobic life, based on the transfer of electrons from substrates to oxygen, inevitably produces free radicals and, consequently, the more poly-unsaturates present in the cell membranes and in the lipoproteins, the more likely it will be that hydroperoxides form, which can be considered a final product of peroxidation and, at the same time, an initial product of peroxidation, because their breakdown leads to the formation of new radicals.

THE FREE RADICAL THEORY OF AGEING

According to the theory of peroxidation by free radicals, ageing and death are simply the consequence of the oxidative stress caused by the free radicals, the ageing process beginning from the very moment of birth, and being the result of cell damage suffered by the organism through the entire span of life caused by the intermediate products of oxygen.

From the above, we can conclude[3] that: 1) reactions involving free radicals are part of normal metabolism; 2) free radicals may accumulate through increased production, diminished destruction, or self-triggered chain reactions; 3) variations of inter-individual sensitivity between free radicals depend on the genetic make-up and environmental influences; 4) during ageing, free radicals accumulate, contributing to functional decline and a greater incidence of illnesses.

In particular, free radicals may cause damage both to membrane phospholipids (with the formation of peroxides from polyunsaturated fatty acids and alteration of functional activity) and to the DNA (with errors in the transcription and transduction of the genetic code).

AGEING OF THE BRAIN

The presence of high concentrations of poly-unsaturated fatty acids in the central nervous system is a basic prerequisite for the neurons to function. However, since the brain, which accounts for about 2% of overall body weight, consumes an inordinate amount of oxygen – about 20% of all the oxygen consumed by the organism – it is understandable that it is particularly exposed to the risk of peroxidation.

In the elderly brain there are numerous deposits of lipofuscin, a pigment believed to consist of a heterogeneous mixture of oxidised proteins and lipids, held together by aggregates involving hydrophobic or covalent bonds[4], and which has been related to the reduced repairing capacity of the DNA[5]. Furthermore, the interaction between neurons in the nervous system is very important. Messages appear to be transmitted through the activation of intra-membrane biochemical phenomena which involve specific membrane phospholipids; on that account, full functionality of the membranes appears to be fundamental for the proper development of such messages and for the complex activity that follow on[6]. Because permeability is conditioned by the chemico-physical state of the membrane, the enzyme activities and the functionality of the receptors on which the neuronal interactions depend, modifications caused by peroxide accumulation and by the subsequent chain reaction of the free radicals may accelerate the ageing process. In addition, it is easy to imagine that during ageing, considerable mutations can occur in the synaptic transmission mechanisms, bearing in mind that such transmission requires not only the presence of neuro-transmitters but also the structural integrity of the membrane (Figure 3)[7].

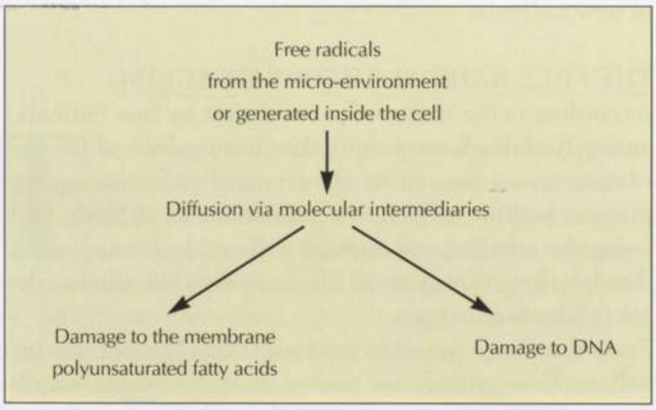


FIGURE 3. Damage caused by free radicals.

CONCLUSIONS AND DIETARY SUGGESTIONS

For the prevention of ageing phenomena, it is important to have a good anti-oxidising capacity, but also to reduce the peroxidisable substrate. Since polyunsaturated lipids are the prime target of free radicals, fatty foods should be selected carefully.

The cholesterol-raising and atherogenic action of saturated fatty acids, the main constituent of animal fats, is well known. The consumption of such fats therefore is not recommended because of their negative effect on the cardio-vascular system. Polyunsaturated fatty acids, which abound in seed oils, on the other hand, tend to lower cholesterol, but in excess they can give rise to problems related to their chemico-physical structure, and this makes them particularly vulnerable to attack from the free radicals of oxygen. The addition of vitamin E to a diet does not seem to prevent the peroxidation process; moreover, it has been demonstrated that an increased dosage reduces the levels of superoxidodismutase[8].

The problem then is not so much a question of increasing anti-oxidisers as of reducing the peroxidisable substrate.

If we admit that the auto-oxidation of tissues increases in the presence of large quantities of polyunsaturated fats and that, at the same time, the atheromatous degeneration of the arteries is increased by saturated fatty acids, then the solution should lie in raising the proportion of monounsaturated, non-atherogenous fatty acids that are not prone to peroxidisation.

The fat that is richest in monounsaturated fatty acids is olive oil, and it has been shown experimentally that it is perfectly compatible with a long life expectancy[9]. It also has a high anti-oxidising capacity owing to the α-tocopherol and the complex of phenolic substances which act synergetically to strengthen the protective anti-oxidising action.

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Chapter 10

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ECONOMIC ASPECTS AND TRADE POLICY

Carlos Tió

THE ECONOMICS OF OLIVE OIL ON THE FATS AND OILS MARKET

The economics of olive oil is somewhat unusual. It is a prestige oil with a market segment that stands apart from other similar products in its sector. Olive oil has loyal customers, especially in the countries and regions where it is produced, who appreciate its special qualities, enabling it to be priced considerably higher than other vegetable oils.

Nevertheless, it should be stated that many other vegetable oils and solid fats satisfy demands for this type of product in large areas in the world and segments of the market where olive oil is either unknown or is not chosen by the consumer for reasons of cultural tradition, price, taste or scarcity of supply.

The economics of olive oil should therefore first be considered within the general context of fats before analysing it on its own. It is significant that olive oil only accounts for between 3.2% and 3.3% of world production and consumption of edible vegetable oils.

The production and consumption of olive oil are concentrated to a large extent within the European Union and specifically in Italy, Spain, Greece and Portugal, although France does produce small quantities. However, olive orchards and olive oil are also a basic agricultural product throughout the Mediterranean Basin, and Tunisia, Turkey, Syria and Morocco also produce and consume considerable quantities.

Outside the Mediterranean area, production is more localised and consumption levels are lower, although markets such as the United States, Australia and Canada have grown considerably. Nevertheless, olive oil is consumed throughout the world, albeit in small quantities and in segments of the market with clearly-defined characteristics, such as high-income social groups, professionals, Mediterranean cooking enthusiasts, ethnic communities of Mediterranean origin and persons concerned about their diet or health.

Olive oil's small but secure position on the world oils market is no doubt due to its very special characteristics. However, the role played by other oils and fats is basically attributable to two factors: low price and usefulness in the production of high-protein content solid residues, essential to animal feeds.

Two types of oil are used today on a massive scale throughout the world: seed oils and tropical oils (palm and lauric). The former are used for direct consumption and in large quantities in the food or other industries. However, the high worldwide demand for oil seeds is due mainly to their use, in crushed form, as meal and cake. These protein products are a staple ingredient in the feedstuffs used for intensive stock breeding. Their widespread use has made it possible to step up the production of poultry and pig meat, and even milk and other products, at very competitive prices.

The combined production of vegetable oils and oilseed meal makes it possible for these oils to be priced very low. In many cases the oil is merely a by-product from the production of protein material.

Some of the agronomic aspects of the production of these crops also influence the low price of seed oils. Soya, sunflower, colza, etc. are annual crops generally grown in suitable areas that require little cultural care and that can be mechanically harvested at low cost.

Seed oils, which are not obtained from a fruit like olive oil, retain unpleasant aromas and flavours from the seeds they come from. They also have very high acidity levels which have to be neutralised and rendered insipid by refining the crude oil, if they are to be suitable for human consumption. This is not necessary with olive oil since, as has been seen, it is the only vegetable oil which can be consumed like a fruit juice in its virgin state, although low-quality olive oils do have to be refined.

Over the last ten years, the so-called lauric oils (copra, palm kernel and coconut) and palm oil have become more popular. These oils have moved in to the lower end of the vegetable oil market, displacing soya oil from many of its uses in the food industry and in other industries in which it had been used since the sixties and seventies in most of the industrialized countries.

However, it should be noted that there is an important cultural factor in the consumption and industrial usage of oils and fats which affects market structure in the various countries. The differences are sometimes the result of a country's domestic production, as is the case of the widespread consumption of olive and sunflower oil in the Mediterranean countries of the European Union or colza oil in the case of Belgium, Denmark, Germany, the Netherlands or the United Kingdom. Similarly, consumption of suet fat and lard is traditionally high in the stockbreeding regions and countries. Alternatively, consumption may be rooted in national traditions which have managed to survive, as is the case for butter in France. Many other countries also produce butter but none have developed a cuisine in which its use is so popular.

Trading traditions, coupled with the development of large-scale stockbreeding and a flourishing food industry, explain the high consumption of soya oil in countries such as Belgium, Denmark and the Netherlands. The persistence of traditions dating from colonial times also explains the consumption of groundnut oil in France and Belgium at levels which are very much higher per capita than those of the neighbouring countries.

In other cases, such as that of corn oil in Italy, markets and uses have been consolidated as a result of a highly successful commercial and marketing strategy.

The large number of products and interests on the world market for oils and fats and their raw materials gives rise to multiple inter-relationships and a complex economy. This has led to a high level of internationalization of the main companies in the sector and to widespread trade throughout the world. It should be remembered that, in the case of palm oil, international trade accounts for eighty percent of world production.

From all that has been said above it is possible to deduce the central role played by the fats sector in the general debate on agricultural policy and international trade. This applies both within the multilateral context of the G.A.T.T. and the International Trade Organisation, and in regional circles such as the European Union. The so-called «Soya Panel», for instance, was the cause of a decade-long confrontation between the United States and the European Union. The interrelationships within the whole complex of fats and oils go much further than a mere jockeying for position on the consumer markets by products which could all, more or less, replace one another. In certain secondary markets, soya, sunflower and colza oil could all, alongside olive oil, substitute one another to a greater or lesser extent.

However the interrelationships go much further than this. They also affect the substitution of whole crops in certain agricultural regions, such as oil seeds, cereals or sugar beet. As a result, a growing demand for chicken or pork meat can spark off the development of oil seed cultivation, to the detriment of other alternative crops. Falling prices on the world cereals market may have been one of the causes of the expansion of oil seed cultivation in countries such as Argentina.

In any case, the main intersectorial relationship in the economy of industrial countries is that between the intensive stockbreeding sectors, which have a great need for protein meals, and the vegetable oils sector. The high demand for cheap meat leaves a surplus of seed oils in markets which leads to very competitive oil prices and has even turned the European Union into the leading world exporter of soya oil although it is known to be a major importer of soya beans.

The complexity of the fats and oils sector makes many countries view it as strategic. The variety of products and the diversity of supply situations create dependence and very powerful interests. It should be borne in mind that producers and users are not normally located in the same geographical areas – hence the intense trade which the sector generates.

During the sixties soya was the indisputable leader amongst fats and oils. Trade was focused mainly between soya-producing countries and industrialized countries which did not produce soya, although there was a traditional trade flow between the former colonisers and their colonies.

The current situation is far more complex. Some highly-dependent countries, such as the members of the European Union, have developed high levels of production of sunflowers, colza and even soya beans. Considerable dependence on imports of soya and derived products has been maintained, while supply has been diversified.

Tropical oils have gained large market shares in industrialised countries and palm, copra and palm kernel oils accounted for 29.26% of the European Community market for edible oils in 1991. The Asiatic countries, the leading exporters of these products, have become a major voice on the world oils market as a result.

On the other hand, many countries have developed a considerable capacity for producing oil seeds and have become major exporters. Examples are Brazil, Argentina and other Latin American countries. It is also probable that Central and Eastern European countries will be developing their own production in the near future.

FIGURE 1
WORLD OLIVE OIL MARKET (IOOC)
International Prices

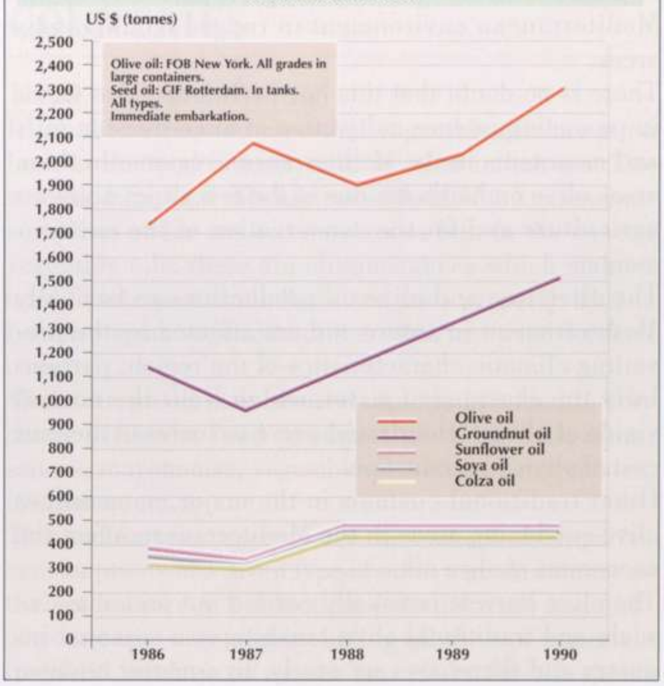
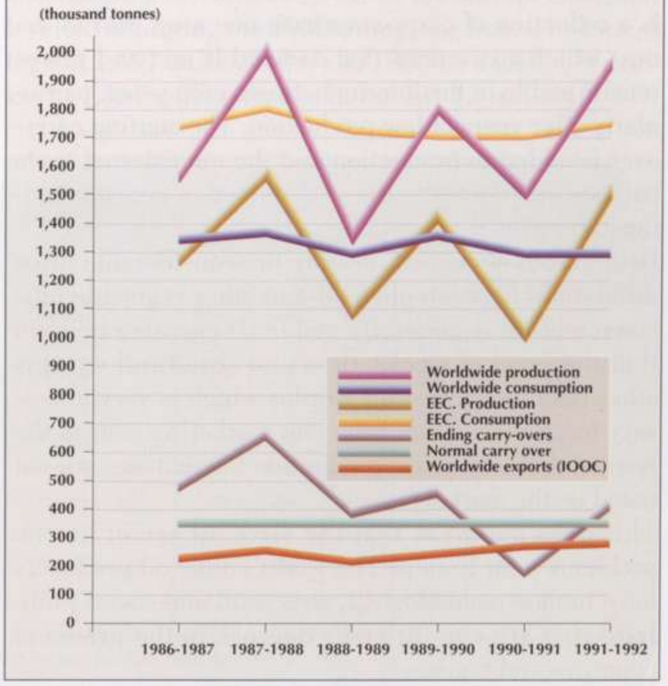


FIGURE 2
WORLD OLIVE OIL MARKET (IOOC)



Despite its unique standpoint from the quality viewpoint, the olive oil economy cannot turn its back on the problems and the interrelationships which exist amongst vegetable oils today. While on the one hand olive oil has to preserve its traditional markets in the face of aggressive competition from other, cheaper oils, it also has to penetrate new markets with no tradition in the consumption of olive oil. In order to do this, it is essential it fully understands the economy of the oils and fats which are dominant there, so that a proper strategy can be worked out.

Figure 1 illustrates the price trends of the main edible oils. The considerable differences between the price of olive oil and seed oils should be noted. During the period from 1986 to 1990 the average price ratio between olive oil and soya oil amounted to a factor of five.

The yield from an olive orchard is usually very irregular and this varying production is known as the alternate bearing pattern. Consumption, however, is usually very stable hence the need for the olive oil sector to ensure the availability of carry-over or buffer stocks from one season to the next so that production fluctuations do not lead to price variations and consequently affect the stability of demand.

The upward trend of world prices as from 1986 reflects, among other things, the entry of Spain into the European Community at price levels very much in excess of those enjoyed by Spain previously.

Figure 1 also reflects the traditional price hierarchy among the different oils produced from seeds. Groundnut oil is priced highest and stands apart from the other seed oils on the graph. In the lower price range but still maintaining a narrow lead, it can be seen how the price of sunflower oil has traditionally been higher than that of soya oil which, after the European Union increased its colza production during the eighties, gave up its place as the cheapest seed oil to colza oil. Way below this is the price of palm, copra and palm kernel oil, not shown on the graph.

Figure 2 illustrates the trend for production, consumption, exports and carry-over from one season to the next and normal carry-over on the world market with regard to olive oil. Production and consumption in the European Union have been included to demonstrate the importance of this region on the world market. In terms of both production and consumption, the European Union has come to account for approximately 75% of the world market.

On the same graph the European Union is shown as one country. This reduces world trade because the intensive inter-Community trade in olive oil is not taken into account.

The graph highlights the marked fluctuations in production at both world and Community level. Consumption, which dropped slightly after 1987/88, started to recover after 1990/91, especially at international level.

World exports also seem to have been rising slightly since 1988/89.

The horizontal line at around the 330,000 tonnes mark is a reflection of carry-over from one crop year to the next which guarantees that demand is met and prices remain stable in the interim between crop years, particularly after years of low production. The starting carry-over is added to production and the net external trade balance and domestic use is deducted to give the ending carry-over.

Both graphs show that, despite the considerable price differences between olive oil and other vegetable oils, consumption is generally stable. It can also be seen that the level of stocks shows no structural surplus other than the carry-over surplus which is very necessary for the transition from one marketing year to the next so that any major production fluctuations are not noted on the market.

This does not mean that the olive oil sector has no problems – far from it! The world's olive oil producers have to face technological, structural and social problems that arise to differing degrees in the producer countries and regions.

In general terms, in most regions, it may be said that little improvement has been made in mechanising the main tasks of pruning and harvesting olives. This means there is still considerable dependence on seasonal labour which gives the sector a marked social role as an employer of labour, but at the same time increases production costs considerably.

Dependence on intensive labour at particular times of the year also has an effect on seasonal migration in olive-growing areas. In some cases there has been a problematic shortage of labour for harvesting in certain parts of the more industrialised producer countries and the problem sometimes arises, albeit to a lesser extent, in the remaining producer countries.

Another essential and determining factor in the economics of olive oil are the botanical characteristics of the crop. It is a tree crop and therefore perennial. This means that starting an olive grove must be seen as an investment, a very different matter from simply sowing oil seeds each year. Being a tree crop, in the first stage of its life it is improductive and then production decreases with old age.

Although usually there is room for reducing unit costs by rationalising and updating cultivation, the above reasons for the high price of olive oil mean that it can never be on an equal footing with other vegetable oils.

The geographical location of olive orchards, mostly spread over the whole of the Mediterranean Basin, gives olive oil production a number of economic and social characteristics which are peculiar to this particular product. In the first place, in many large areas, it is a monoculture that has adapted perfectly to the Mediterranean environment in rugged mountainous areas.

There is no doubt that this has been a decisive factor in promoting intense cultivation of olive trees on hills and mountains in the Mediterranean regions. In these areas olive orchards are one of the few alternatives for agriculture and for the conservation of the environment.

The olive tree and olive oil production are basically Mediterranean in nature and are affected by the prevailing climatic characteristics of the region, particularly the shortage of water, which limit the normal yields of olive orchards and serve to increase the unit cost of olive oil production.

Other traditional customs in the major monoculture olive-producing areas in the Mediterranean affect the economics of olive oil.

The olive harvest is usually carried out on a massive scale and traditional olive crushing is a seasonal industry and therefore very costly. In a matter of days, enormous quantities of olives are picked without, for the most part, any adequate facilities for reception, storage or conservation between harvesting and crushing.

Hence the traditional «fustiness» of the product with the consequences for quality that are only too well-known, since the resulting high acidity level has to be corrected by refining.

Moreover, the oilseed processing and distribution sector is, as a rule, concentrated in a very few hands. In the main European countries it is a sector with highly-concentrated markets where multinational companies predominate.

The olive oil sector on the other hand, barring some exceptions, is much more scattered. This is an economy which forms part of the social and economic structures of the producer regions at every stage in its production process. In most cases the enterprises are family concerns, cooperatives or small-scale companies.

The sector's social and political importance in the Mediterranean countries is linked to its major dependence on labour, making it an irreplaceable economic alternative in many regions which are usually underdeveloped with little local industry.

THE ECONOMICS OF OLIVE OIL IN THE MAIN PRODUCER COUNTRIES

THE EUROPEAN UNION

It should be remembered that vegetable oils are used both in the food industry and in other industries. The so-called mineral oils are not suitable for human consumption under any circumstances but, in the case of vegetable oils, there are circumstances which make it hard to interpret trade flows and uses properly. This is because some vegetable oils are not just used for food uses.

Moreover, an oil may be used directly or added to very many different food products such as margarine, sauces, mayonnaise, vegetable preserves, fish, pastries, ice cream, etc.

This makes it necessary to use the concept of «apparent consumption» of a given type of oil in a given country as the net balance of production, external trade and end-of-year carry-over and including all the raw materials involved, such as oil seeds, as well as the oils themselves, whether crude or refined.

From «apparent consumption» it is not clear whether a finished product containing oil has been consumed in the country where it was made or exported. Nor is it usually possible to determine either the date of sale or actual consumption in the case, for example, of products for the food industry intended for long-term storage such as preserves.

It should be emphasized that a large number of different products are used and consumed on the EU edible oils market including five main oils – soya, sunflower, colza, palm and olive oil. All five account for 80% of apparent consumption. None of them has a clearly dominant share of the market and shares range from a minimum of 13.9% for olive oil (including pomace oil), up to a maximum of 19.7% for sunflower oil in 1991 (Figure 3).

This situation gives consumption varying from 5.3 kgs per person per year for sunflower oil to 3.5 kgs for olive oil (3.8 kgs if olive pomace oil is included), although a recent increase in consumption of olive oil raised the level to 4 kgs per person per year (4.33 kgs if pomace oil is included) in 1992-93. Average consumption of vegetable oils was 27.5 kgs per person per year in 1991.

The grand total for the apparent consumption of vegetable oils has grown progressively in recent years, reaching 20% in the 5-year period from 1987 to 1991. Palm oil made spectacular progress, registering a 67% increase over the same period. There have also been major increases in the consumption of sunflower oil (+48%) and colza oil (+27%).

Consumption of soya bean oil in the European Union levelled off during the 1980s, dropping from a historical high of 1,697 million tonnes in 1980 on the EEC-9 market to 1,561 million tonnes in the EU-12 in 1991.

TABLE 1
OLIVE OIL AND OLIVE POMACE OIL CONSUMPTION IN THE EU
(Thousand tonnes)

	Olive oil				Olive pomace oil
Crop year	EU-12	Spain	Italy	Greece	EU-12
1985-1986	1,289	370	640	210	102
1986-1987	1,324	378	670	200	85
1987-1988	1,375	420	680	200	97
1988-1989	1,300	396	630	200	102
Average 1986-1989	1,322	392	655	203	97
1989-1990	1,300	388	626	205	96
1990-1991	1,211	394	540	200	96
1991-1992	1,360	430	630	195	107
1992-1993*	1,374	431	640	190	115
Average 1990-1993*	1,311	411	609	198	103

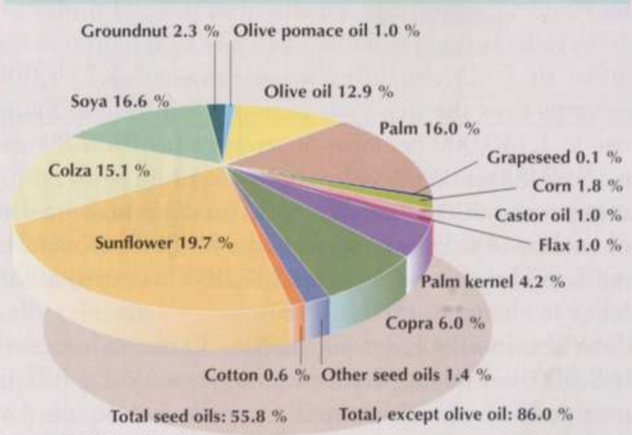
* The figures for 1992-1993 are provisional.

Source: International Olive Oil Council.

There has been reasonable stability in olive oil consumption within the European Union, with maximum variations of -8% and +4% in the average value of both 4-year periods. In the last few years there has been a clear upward trend (Table 1).

Consumption continues to grow at a very good rate in France, Portugal, the United Kingdom and Germany, and moderately so in Spain. It has dropped slightly in Greece and is fluctuating in Italy despite recent signs of recovery of the high traditional level of consumption.

FIGURE 3
MARKET SHARES OF THE DIFFERENT TYPES OF OIL IN THE EUROPEAN MARKET (UE-12) IN 1991



Sources: FEDIOL and IOOC

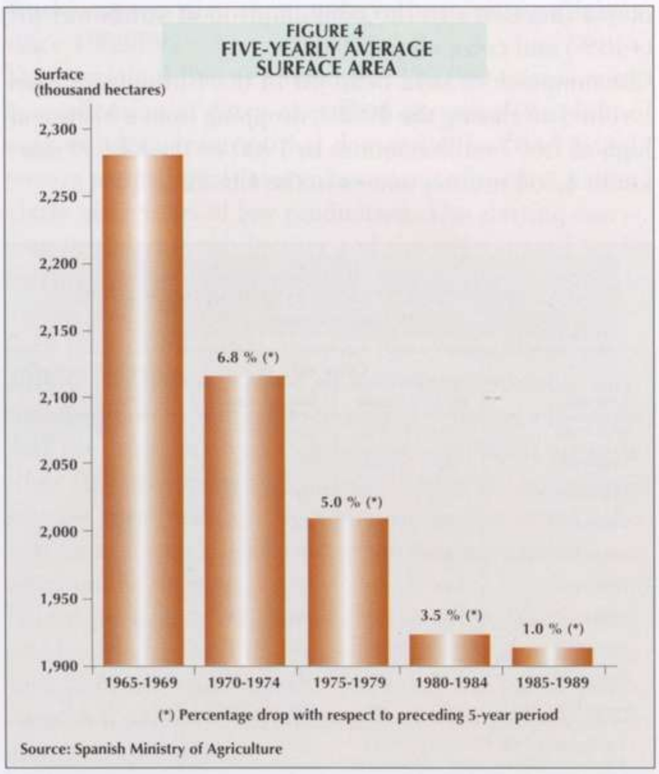


FIGURE 4
FIVE-YEARLY AVERAGE SURFACE AREA

(*) Percentage drop with respect to preceding 5-year period

Source: Spanish Ministry of Agriculture

Spain

In Spain, the area of land cultivating oil olives seems to have more or less stabilized at slightly over 1.9 million hectares. Spain has the largest acreage of olive groves in the world and is also the top world producer and exporter. The trend towards a reduction of the area of land under oil olives seems to have levelled off since Spain joined the European Union. In 1991 the area was 1,944,000 hectares (Figure 4).

It should also be pointed out that the trend for recent years has not been the same in all the producer regions. The trend in Andalusia is of particular interest because there olives account for 60% of the area under cultivation and 75% of Spain's production of olive oil. The rising trend in Andalusia for the area of land under oil olives reflects this changing tendency with a drop in the curve in 1985. So after an average of 1,124,000 hectares over the five-year period 1980-84, the figure rose to 1,140,000 hectares on average for 1985-89 and to 1,172,000 in 1990.

In other regions that traditionally produce high-quality oil such as Aragon which accounts for 50,000 hectares and Catalonia accounting for 117,000 hectares, a tendency to change started in 1987.

However, in other regions such as Extremadura with 168,000 hectares, the tendency towards a fall in acreage has been maintained. Over the last decade Extremadura lost 13% of its oil olive orchards. Castilla La Mancha, Spain's second olive-growing area, has olive orchards covering 271,000 hectares.

Olive yields have been moving upward over the whole of the country, although production is still low. It is estimated that in twenty years' time average productivity will have risen from 882 kgs per hectare on average for the five-year period 1965-69, to 1,328 kgs per hectare over the five years from 1985-89, that is, by 50%. Average production, too, has increased in recent years. Over the five-year period 1985-89, for the first time, average production was in excess of half a million tonnes of olive oil, namely, 514,000 tonnes (Table 2).

TABLE 2
AVERAGE OLIVE OIL PRODUCTION (tonnes)

1985/1986-1988/1989	505,000
1989/1990-1992/1993	601,000

Source: International Olive Oil Council

Average olive oil consumption for 1989/90 - 1992/93 was 410,000 tonnes, although this figure has increased to over 430,000 tonnes since then, the equivalent of 11 kgs per person per year. In addition, 70,000 tonnes of pomace oil were consumed.

The number of oil mills throughout the country is very high although much lower than in Italy. Whereas in Italy there are probably more than 8,000 mills, in Spain there are no more than 2,500 although probably only 2,000 of them are still in operation.

80% of oil refining has been taken over by packing concerns of which there are currently 430.

The level of concentration in the Spanish oil sector is shown by the fact that in 1991 the ten leading olive oil packing companies accounted for a 66.5% share of the total olive oil market. In the case of sunflower oil the situation is very similar. The ten leading packers of sunflower oil have a 63.6% share of the total market.

Traditionally, Spain has been the world's leading exporter of olive oil. As from 1986, Spanish exports have increased steadily. The level of exports in this sector varies according to the harvest, but it is also dependent upon annual production by Spain's traditional buyer, namely Italy. The export average for the period 1989/90 - 1992/93 amounted to 233,000 tonnes.

It should also be pointed out that in recent years Spain has begun importing olive oil, averaging 34,000 tonnes for the period from 1989/90 - 1992/93.

When analysing vegetable oil consumption in Spain, it should be remembered that, on 1 January 1991, Spain underwent a trade liberalisation process following the signature of its accession to the EU.

As a result, the 1990/91 average has been used to analyse apparent consumption of vegetable oils other than olive oil. In this period, total oil consumption amounted to 1,112 million tonnes, with a 35.1% market share for olive oil, plus 3.5% for pomace oil. The Spanish consumer market is mainly divided between olive and sunflower oils.

Average consumption of sunflower oil was 366,000 tonnes, 9.4 kgs per person per year, with a market share of 33%.

Soya oil has maintained a small market share in direct consumption of bottled oil, although its apparent consumption amounts to an average of 169,000 tonnes, equivalent to a per capita consumption of 4.3 kgs per year and a global market share of 15%.

After Spain joined the European Union, palm oil consumption grew considerably, increasing from 12,000 tonnes in 1985 to 84,000 tonnes in 1991. Its average market share is 5.7%, with a per capita consumption of 1.6 kgs per year.

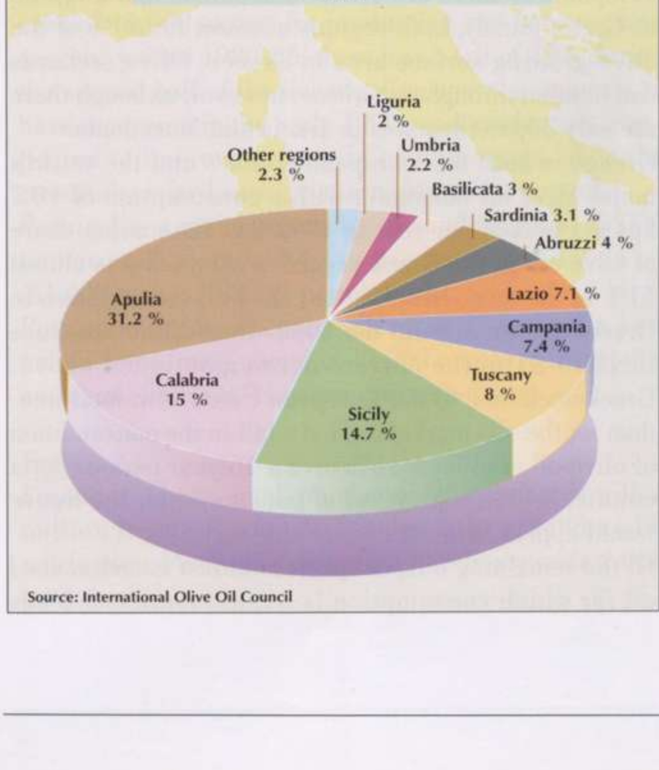
Added to this are copra and palm kernel oils for which consumption amounted to an average of 46,000 tonnes, another 4.1% of the oil market.

Other oils, such as colza and corn oils, hardly amounted to a joint 2% of the market.

Italy

The total number of olive orchards under regular cultivation in Italy is 1,176,000 hectares, 98.6% of which are in full production. The regional breakdown (Figure 5) is as follows :

FIGURE 5
ITALY



Source: International Olive Oil Council

Olive orchards cover 7.54% of Italy's total area of land under cultivation. Approximately 60% are situated on hilly land. There are 1,094,030 holdings planted with olives so most are very small, with an average area of 1.1 hectares, and are run on a family basis.

The breakdown of these olive orchards according to size (Table 3) is as follows :

TABLE 3

Area in hectares	%
Up to 2	52.5
5 to 10	25.7
10 to 20	11.7
20 to 50	3.0
Over 50	1.4

Source: International Olive Oil Council

According to Italian government data, 65% of olive orchards produce fewer than 300 kgs of olive oil, while 15% produce from 300 to 500 kgs (the EU limit for aid to small producers). 12% produce between 500 and 1,000 kgs and only the remaining 8% produce more than 10,000 kgs.

Average yields vary, depending upon the regional characteristics. In mountainous areas yield is estimated at 2,150 kgs of olives per hectare, in hilly areas at 2,560 kgs and on flat land at 3,890 kgs.

The number of oil mills is still very high but has dropped in recent years. At present there are estimated to be approximately 8,000, of which 500 are cooperatives. There are also 90 olive pomace oil extraction plants and 30 olive oil refineries.

Italian olive oil production increased considerably during the sixties and seventies and the trend continued, albeit at a slower rate, in the eighties although it has dropped again in the last few years (Table 4).

TABLE 4

Period	Production (tonnes)
1985/1986-1988/1989	573,000
1989/1990-1992/1993	462,000

Source: International Olive Oil Council

Italian olive oil exports have also risen considerably in recent years, from an average 82,000 tonnes for 1985/86 - 1988/89 to an average 122,000 tonnes in 1989/90-1992/93. Exports in small containers are especially relevant.

Nevertheless, Italy is short of oil and is the world's top importer. Imports have increased greatly over the last 10-year period. Average imports for the period from 1985/86 to 1988/89 amounted to 216,000 tonnes, while between 1989/90 and 1992/93 they rose to 295,000 tonnes per year on average. Spain, Greece and Tunisia are their main suppliers.

Italian domestic olive oil consumption is 609,000 tonnes per year, this being the average for the period from 1989/90 to 1992/93 and the equivalent of 10.5 kgs per person per year.

According to official figures, olive oil distribution is as follows:

- 30% retail sales
- 20% producer family consumption and direct sales by producers
- 17% sales by correspondence
- 33% for catering and industrial uses

Italy is estimated to consume 40% in the form of extra virgin oil, 10% in olive pomace oil and 50% in blends of virgin and refined oils. The latter category is classified simply as «olive oil» according to European Commission standards.

Extra virgin olive oil has been the driving force behind increased consumption of all olive oil categories during the last decade. Experts are of the opinion that there is still room for further growth. The only disadvantage is the high price of these oils.

In June 1990, the Italian government adopted an intervention plan specifically for the olive sector. The aim was to start restructuring olive groves in depth. The plan also covers modernisation of the milling sector.

The table 5 shows the trend for apparent consumption of the main vegetable oils in Italy.

TABLE 5

	1990	%	1980	%	Increase %
Soya	241,000	16.2	300,000	21.6	-24.5
Sunflower	158,000	10.6	99,000	7.1	59.5
Total, seeds	528,000	35.5	537,000	38.6	-1.6
Olive Oil	633,000	42.6	621,000	44.7	-1.9
Palm oil	130,000	8.7	60,000	4.3	116.6
Copra	55,000	3.7	49,000	3.5	12.2
Palm Kernel	19,000	1.2	5,000	0.3	280
Corn	91,000	6.1	75,000	5.4	21.3
Grand total	1,484,000	100.0	1,388,000	100.0	6.9

Note: 1990 rather than 1991 has been used as olive oil consumption dropped suddenly in Italy in 1991 and then returned to its usual consumption levels.

Olive oil represented 36.6% of the overall vegetable oil market in 1991, and olive pomace oil 2.8% with 42,000 tonnes.

Overall consumption of vegetable oils in Italy has hardly increased at all over the last ten years. The rise of 100,000 tonnes, or 6.9%, over the 10-year period can be considered stable. Both seed oil and olive oil consumption have remained stable although in fact both oils lost part of their market share, two points for olive oil and three points for seed oils, because their growth was slower than the market growth rate.

The biggest fall in consumption was recorded by soya oil, at nearly 20%, losing almost 5 percentage points in market share over the last decade. This fall speeded up in 1991 when soya oil consumption was only 190,000 tonnes, 12.8% of the vegetable oil market, giving the lead position in seed oil consumption to sunflower oil. Consumption per capita is 3.3 kgs per year.

The consumption of colza and sunflower oils is increasing rapidly on the Italian market. Sunflower oil is now the top vegetable oil, excluding olive oil, at 194,000 tonnes, 3.35 kgs per person per year, with a 13% market share.

Consumption of colza oil rose to 116,000 tonnes in 1991, the equivalent of 2 kgs per person per year, with a 7.8% share of the Italian oil market.

Tropical oils increased from a market share of 8.1% in 1980 to 13.6% in 1990 and 14.5% in 1991, making up for the loss in market share of soya oil.

Greece

Greek olive orchards account for 15% of the country's cultivated land. Olives are grown over 850,000 hectares and there are a total of 26 million olive trees. Average production over the period 1990-93 was 300,000 tonnes with domestic consumption estimated at almost 200,000 tonnes. Consequently Greece is a major net exporter of olive oil, with an average of 100,000 tonnes.

The largest olive orchards in Greece are located in the centre and south of the country and in Crete. In the Peloponnese there are 169,000 hectares, and 200,000 in Crete; jointly, both regions account for 60% of the olive-growing surface area in Greece. Olive orchards can be seen throughout Greece, however, although there are only 30,000 hectares in Tracia and Macedonia.

Greece is both the European Union's and the world's major olive oil consumer with a consumption of 18.7 kgs per person per year in 1992/93. The market share of olive oil on the Greek vegetable oil market is almost 51% of the total. Despite this, olive oil consumption in Greece fell throughout the 1980s from 239,000 tonnes in 1980-81 to the current figure mentioned above. Greek accession to the European Union with total freedom for the oils market caused a fall in the consumption of olive oil of at least 16% over a 10-year period. For a country with a high level of consumption, the figure would appear to be on the low side.

Of the remaining oils, of special interest is cotton seed oil for which consumption is 39,000 tonnes, 3.8 kgs per person per year, and the market share is 9.9%. Soya oil takes second place for the Greeks, with apparent consumption of 68,000 tonnes in 1991, 6.7 kgs per person per year, and a market share of 17.2%.

In 1980, sunflower oil had not been heard of in Greece. From the period 1983-84 to 1991 consumption almost tripled, rising from 12,000 tonnes to 33,000 tonnes in 1991 (3.2 kgs per person per year) and reaching a maximum in 1988 of 46,000 tonnes. Consumption now appears to be falling off.

Corn oil has a considerable presence on the Greek market, 2.1 kgs per person per year and 5.6% of the whole vegetable oil market.

Lauric oils are hardly used at all in Greece. Palm oil is more important, with consumption of 18,000 tonnes, 1.7 kgs per person per year, and a 4.5% market share.

In overall terms, Greece is a strong consumer of vegetable oils, with a per capita consumption of 38.9 kgs per person per year.

Portugal

Portugal is one of the main olive oil producers and consumers. Average production is approximately 35,000 tonnes but the figure varies greatly from year to year. In recent years, consumption has been over 40,000 tonnes and, during the period from 1990-93, imports (14,000 tonnes) were higher than exports (10,000 tonnes). Consumption per capita (4.3 kgs per person per year) is still far below levels in other Mediterranean producer countries such as Spain, Italy or Greece. There are 22 million olive trees in Portugal, on half a million hectares of land, equivalent to 7% of all the land under cultivation. Over the period 1980-90 Portugal produced and consumed progressively less olive oil. Compared with averages of 45,000 tonnes for production and consumption over the period 1980-85, there was a fall of 22% during the second half of the decade. Consumption appears to have recovered in the early 1990s and production is expected to improve greatly in coming years, once the strong alternate bearing pattern gets under control.

Portugal is a major consumer of sunflower oil (95,000 tonnes equivalent to 9.6 kgs per person) and soya oil (51,000 tonnes, 5.2 kgs per person).

Portugal also imports palm oil, copra oil and palm kernel oil, consuming a total of 43,000 tonnes of these oils, an overall figure of 7 kgs per person per year.

France

France still has a small number of olive orchards with 4 million trees covering 40,000 hectares of land under cultivation. Average production barely exceeds 2,000 tonnes.

France has been increasing its consumption of olive oil rapidly in recent years: 23,000 tonnes in 1980-81, 30,000 tonnes in 1989-90 and 40,000 tonnes in 1992-93. This last figure is equivalent to an annual consumption of 0.7 kgs per person, a very low level considering the French market's potential. Bearing in mind its cultural and geographical characteristics, France ought to be consuming more olive oil.

As a high consumer of butter (7 kgs per person per year) and animal fats (5 Kgs), France is the lowest consumer of vegetable oils in the whole of the European Union, with only 17.6 kgs per inhabitant per year, excluding olive oil.

The French market would also appear to be very diversified. It is the European Union's largest consumer of groundnut oil. At 105,000 tonnes, consumption is equivalent on a per capita basis to 1.8 kgs per inhabitant per year. The share of vegetable oils, apart from olive oil, is 10.4% of the market.

Another characteristic of this French market is its low apparent consumption of soya oil, which accounts for only 1% of the French market, with a per capita consumption of 0.17 kgs, the lowest in the whole of the EU. Soya oil, which had reached consumption levels of 110,000 tonnes in 1980, has now dropped to 10,000 tonnes.

The leader on the French market for vegetable oils is, without doubt, sunflower oil. Per capita consumption is 7.5 kgs with a market share of 42.3%. Consumption of sunflower oil in France has grown steadily and in 1991 reached 425,000 tonnes.

There has been considerable expansion of colza oil on the French market since 1985, with an apparent consumption of 205,000 tonnes in 1991, thus registering an increase of 13 % in six years.

Palm oil (9.6%), copra (6.9%) and palm kernel oil (1.6%) have a small but growing market share, particularly palm oil.

Germany

Germany's olive oil consumption is traditionally low but is nevertheless growing. Consumption of 4,000 tonnes in the early 1980s has tripled in only a decade, with per capita levels of 0.15 kgs.

As far as other oils are concerned, Germany alone accounted for 24.4% of the overall consumption of vegetable oils in the EU in 1991 with overall consumption of 1,994 million tonnes, 24.8 kgs per person per year, in addition to 6 kgs of butter.

94% of the German market is shared between 6 types of oil: soya, with consumption per person per year of 5.6 kgs (447,000 tonnes, 22.4%); colza with 5.1 kgs per person (409,000 tonnes, 20.5%); palm oil (4.7 kgs per person, 381,000 tonnes or 19.1%); sunflower oil (3.2 kgs per person, 258,000 tonnes or 12.9%); copra (2.5 kgs per person, 206,000 tonnes or 10.3%), and palm kernel (2.1 kgs per person, 172,000 tonnes or 8.6%). All these figures refer to 1991.

Belgium

In Belgium consumption of olive oil, although fairly low at 2,700 tonnes, has practically tripled in recent years, with consumption per capita now at 0.27 kgs.

Apparent consumption of vegetable oils is very high, at 42.6 kgs per person per year, the highest figure in the EU after the Netherlands. In terms of their market share, seed oils account for 65.5% of the market (29.3% soya, 13.6% colza and 18% sunflower). Palm oil accounted for 21% of the market in 1991.

Denmark

Consumption of olive oil in this country has increased considerably, although it was only consuming 1,200 tonnes in 1992/93, 1.2 kgs per inhabitant per year.

The Danish market is shared by the seed oils (59.3%), palm oil (28.1%) and the lauric, copra and palm kernel oils (10.7%). Of the seed oils, soya with 33% and colza oils predominate in this market segment.

Ireland

With consumption of vegetable oils at 18.3% kgs per inhabitant per year, Ireland, together with France, is the smallest consumer of oils in the whole of the Community. However, butter consumption (3 kgs per person per year) and animal fats (1 kg) have dropped rapidly in recent years.

Ireland is the European Union country which consumes least olive oil, barely 800 tonnes in 1992-93 although this represents 0.23 kgs per capita each year. The country consumed a total of 64,000 tonnes of vegetable oils other than olive oil in 1991. Of these, 72% are seed oils with soya accounting for 26.5%, colza 25% and sunflower oil 14%. Palm, copra and palm kernel oils have a 25% share in the Irish oil market.

The Netherlands

The Netherlands has the highest apparent level of consumption for vegetable oils for the whole of the European Union. The figure amounts to 63.6 kgs per inhabitant per year, a figure which has to be interpreted in conjunction with the Netherlands' role as a major producer and exporter of margarine, sauces and other industrial food products, which incorporate vegetable oils and fats to a greater or lesser extent. This is confirmed by the structure of apparent consumption in the Netherlands, showing palm oil at 15.4 kgs per inhabitant per year and soya oil at 13.8 kgs as leaders on the Dutch market.

Oil made from copra and palm kernels is also used in very large quantities in the Netherlands, representing a 22% share of the market in 1991.

In 1992-93, 1,700 tonnes of olive oil (0.1 kgs per inhabitant per year) were consumed, and this product is very much a dark horse. Its consumption has increased significantly over recent years and has almost tripled since 1983-85.

United Kingdom

Although only a small consumer of olive oil (0.2 kgs per inhabitant per year), the United Kingdom is showing a strong tendency towards increased consumption of olive oil, which multiplied by 5.5 in the period between 1983-85 and 1992-93, when consumption increased from 2,200 tonnes to 12,100 tonnes.

The market for other oils is spread between seed oils (61.8% of the market and 14.7 kgs per capita) and palm, copra and palm kernel oils (8.4 kgs) of which palm oil is clearly dominant (6.4 kgs). The leader on the British market is undoubtedly colza oil, with total consumption of 440,000 tonnes in 1991 (7.6 kgs per person per year) as opposed to 207,000 tonnes of soya oil (3.6 kgs) and 167,000 tonnes of sunflower oil (2.9 kgs per person).

OTHER PRODUCER COUNTRIES

The production of olive oil outside the European Union is basically concentrated in North Africa and the Middle East, mainly in Tunisia and Turkey which are producer countries and traditional exporters, although Algeria, Morocco and Syria also produce olive oil intended principally, to date at least, for domestic consumption. Morocco has been consuming rather more olive oil in recent years.

With the exception of Tunisia, olive groves are cultivated in a very traditional way in most of these countries. Yields are for the most part very low and the quality of the oil produced is improving only slowly.

Tunisia

If we exclude the EU, Tunisia is the world force in the olive oil sector. The country has been making a great effort to restructure, modernize and improve the quality of its oils and has expanded its acreage considerably.

The area of land under olives for crushing in Tunisia was slightly below 1.4 million hectares in 1986, the largest in the world after Spain. The number of olive trees is estimated at 54 million, of which 11 million (20%) were still not in production in 1986.

This fact is proof of the clear expansion of Tunisian olive production, particularly over the last five years. Traditionally, the average for Tunisia's olive oil production has been 100,000 tonnes per year. However, average production over the period 1990/91 - 1993/94 was 183,000 tonnes and it reached 250,000 tonnes in 1991/92.

There has therefore been evident expansion in Tunisian olive oil production although it is still limited by the traditional alternate bearing pattern of the olive.

The market is controlled by the ONH (National Office for Oil) which is a marketing monopoly for olive and olive pomace oil that collects all the oil produced through authorised intermediaries. The oil mills, under the control of the ONH, centralise production. Oils, bottled by the ONH or recognized agents, are sold at official prices. After the 1993/94 harvest, the sector began a liberalisation process. In recent years, Tunisia's domestic consumption of olive oil has been 60,000 tonnes. Average exports amounted to 125,000 tonnes between 1990/91 and 1993/94, a spectacular increase compared with previous figures.

Tunisia has a preferential export quota to the EU of 46,000 tonnes. Historically, exports before the 1990s were slightly higher than this quota. This is a major trade sector for providing foreign currency for the Tunisian economy.

The change of situation experienced by Tunisia's oil sector is due to the effort which the country has made to modernize and expand olive cultivation. This effort has not finished, since in the period 1987-91 the Seventh Development Plan was put into action, the objectives of which were to improve olive growing qualitatively and quantitatively, together with the mills and refineries involved in the production of oil.

Tunisia covers the remainder of her domestic consumption needs by imports, soya oil (87,000 tonnes in 1987) and colza oil (56,000 tonnes in 1989).

Turkey

This country's olive growing potential, at 640,000 hectares under olives for crushing and a total of 85 million trees, of which about 8% have not yet started to bear fruit, is smaller than Tunisia's.

Turkey's averages for olive oil production were of the order of 61,000 tonnes in the period from 1990/91 to 1993/94. This represents a drop in its traditional production levels of an average 87,000 tonnes in the period 1983/86 and 75,000 from 1987 to 1990. Currently, domestic consumption is some 50,000 tonnes, and there is less oil available for export, with a fall from 35,000 tonnes in the mid-1980s to little more than 8,000 tonnes on average in the period from 1990/94. Turkey sometimes has to import small quantities of olive oil.

Turkey is also a major producer of cotton (670,000 hectares) and sunflowers (830,000 hectares) which enabled the country to produce 500,000 tonnes of sunflower oil and 150,000 tonnes of cotton oil in 1989. In foreign trade in seed oils, Turkey's position as an exporter of sunflower oil should be stressed (70,000 tonnes) although it also imports soya oil (154,000 tonnes).

Overall, Turkey consumes 760,000 tonnes of seed oils. In Turkey, trade in oils is entirely free.

Morocco

Morocco has an olive-growing potential of 365,000 hectares, accounting for 36 million trees, mostly producing dual-purpose olives, 21% of which have not yet started to bear fruit.

With this potential production and a further 15,000 hectares to be planted over the next few years (1.5 million more olive trees), Morocco could bump up its production even further. Production averaged 41,500 tonnes over the period 1990/91 to 1993/94 and is expected to grow to around 60,000-75,000 tonnes by 1997.

Morocco consumes some 40,000 tonnes of olive oil per annum and exports a little over 3,000 tonnes per annum.

It is also a small producer of other vegetable oils. In 1990, 160,000 hectares of sunflowers were sown and in 1991 170,000 hectares, with an oil production of 62,000 tonnes. In order to satisfy domestic consumption assessed at 240,000 tonnes of seed oil, Morocco had to import 110,000 tonnes of soya oil and 70,000 tonnes of colza oil.

Generally speaking, Morocco's oil producing industry still needs to be modernized to enable the country to increase the proportion of quality oils produced.

Algeria

This country has some 175,000 hectares of land under olives, both oil and dual-purpose varieties, with 20 million trees, of which only 10% are still to begin producing. Algeria has doubled its olive oil production in a matter of years. Compared with an average 13,000 tonnes between 1986/87 and 1989/90, Algerian production increased to 26,000 tonnes from 1990/91 to 1993/94, all for domestic consumption.

In 1989 there were plans for 3,000 hectares of new olive groves and of these about 2,500 hectares have been planted.

Algeria has set in motion a programme for furthering olive growing and modernization of the oil-producing industry as part of a «strategy for the development of olive cultivation up to the year 2.000».

Israel

In Israel the area of land under olives is 10,000 hectares with 1.6 million olive trees, producing some 6,000 tonnes of olive oil, almost all consumed domestically since Israel has only just started exporting olive oil and figures barely amount to 500 tonnes a year.

Israel may be planning to plant additional olive orchards over the next few years, although only on a very small scale.

Egypt

In 1990 Egypt had 3.5 million olive trees, and it was planned to plant another 400,000 in the short term to enable the country to produce a mere 1,000 tonnes of olive oil, while importing some 1,000 tonnes a year to satisfy domestic demand which is estimated at 2,000 tonnes.

Egypt's main oil production is cotton with 428,000 hectares and 90,000 tonnes of oil, and soya with 65,000 hectares and 25,000 tonnes of oil. The country also produces small quantities of sunflower, groundnut and sesame oils.

In order to satisfy domestic consumption of seed oils of 510,000 tonnes, Egypt needs to import 144,000 tonnes of cotton oil and 225,000 tonnes of sunflower oil.

Libya

Libya's average production in recent years was only 8,000 tonnes of olive oil. Libya's traditional imports have recently dropped to 1,000 tonnes, as has domestic olive oil consumption since 1989/90. Currently consumption is approximately 9,000 tonnes, although the average for 1991/94 is somewhat higher (12,600 tonnes). In the mid-1980s, Libya was consuming over 50,000 tonnes.

Syria

Syria is the major olive-growing country in the Middle East with 366,000 hectares under olive trees, most being dual-purpose varieties. The total number of olive trees in 1989 was 41.3 million, of which 34% were not yet in production at that time.

It is planned to plant new olive orchards over an additional 12,500 hectares accounting for 2 million more trees. Olive oil production of some 70,000 tonnes is all been consumed domestically since Syria does not export olive oil.

Jordan

Jordan has 55,000 hectares of land under olives with 5.4 million trees of which 26% are not yet producing, and production averages 9,000 tonnes.

Consumption is slightly higher than production, approximately 11,000 tonnes, making it necessary to import small quantities amounting to 3,000 tonnes a year. Jordan's exports are not usually more than 1,000 tonnes.

In addition, the country imports some 30,000 tonnes of sundry vegetable oils, more than half palm oil, and 14,000 tonnes of butter.

Lebanon

Lebanon has an olive oil deficit. Production was slightly over 5,000 tonnes and consumption over 7,000 tonnes a year, so the Lebanon has to import some 2,500 tonnes of olive oil each year. Recently, the country has started to export small quantities of olive oil.

Former Yugoslavia

This country had 30,000 hectares of land under olives with some 4.1 million trees in 1987. The average for production over the period 1988-92 was 5,000 tonnes of olive oil per year which has since dropped to 2,000 tonnes a year.

The level of consumption, traditionally around 6,500 tonnes, has had to adapt to the level of production after foreign trade was cut because of the situation still existing at the time of publication of this information. The country used to import on average 5,000 tonnes of olive oil a year.

Before the war, there was an investment programme for the olive oil sector with plans to plant 1,800 new hectares of olive trees, which it was hoped would increase production to 9,000 tonnes.

Cyprus

The island of Cyprus has 7,300 hectares of olive groves with 1.6 million olive trees. No new groves are planned. With current production of olive oil at 3,000 tonnes and consumption slightly lower, Cyprus has been able to start exporting (in 1993/94).

Cyprus imports some 20,000 tonnes of soya and sunflower oil.

Argentina

Argentina has a token production of 9,000 tonnes of olive oil by comparison with 2.5 million tonnes of other vegetable oils. Approximately half of the olive oil is consumed domestically while the other half is exported.

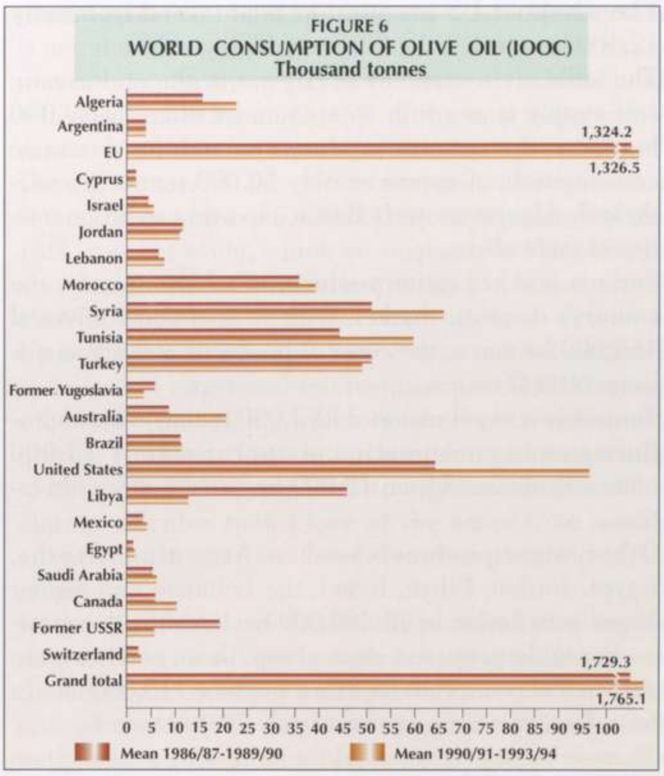


FIGURE 6
WORLD CONSUMPTION OF OLIVE OIL (IOOC)
Thousand tonnes

Other producer countries

Many countries all over the world are small producers of olive oil, with an overall production of some 42,000 tonnes per year, notably Iran (2-3,500 tonnes), Mexico (2,500 tonnes) and the United States (1,000 tonnes).

INTERNATIONAL CONSUMPTION OF OLIVE OIL

The international olive oil market may be considered to be balanced at present, although both world production and consumption are growing moderately. Production grew by 137,000 tonnes between the average for the four-year period 1986/87 to 1989/90 and the four-year period 1990/91 to 1993/94. Recently, during the last-mentioned period, it reached an average of 1,833 million tonnes.

World consumption over the last four years between 1990/91 and 1993/94 was 1,831 million tonnes. Vis-à-vis the average for consumption over the previous four-year period, world consumption has risen by 66,000 tonnes.

Among the countries which do not produce olive oil there has been a general increase in consumption, especially in the United States, Canada, Australia, Japan and Saudi Arabia. The level of consumption reached in the United States is of particular significance, amounting to 115,000 tonnes in the 1993/94 crop year.

These consumption parameters for olive oil at world level are reflected on the attached table (Figure 6).

THE ECONOMICS OF TABLE OLIVES

The economics of table olives is closely linked with olive cultivation and oil production in the producer areas although industrial processing and marketing involve separate specific activities.

It should be remembered that many varieties of olive are dual-purpose, so can either be processed as table olives or sent for crushing. This makes it difficult to hazard a guess at the production potential for table consumption. This fact upsets markets as in some years a large proportion of production may be diverted to direct consumption instead of being used for crushing, or vice versa, depending on prices and the aid available in both markets.

The high level of domestic consumption of oil by producers themselves also helps create an unclear picture of the market.

The production of table olives is costly, particularly if harvesting is done manually to protect the fruits from damage.

In many producer regions, table olives are produced in small-scale family-run units although in many places cooperatives have been set up in order to modernise processing while diversifying the trade preparations produced and facilitating trade.

If we regard what is produced in Argentina and the United States as an exception, table olives are an exclusively Mediterranean economy. The sector is currently expanding, both from the production angle and in terms of consumption and trade.

The area of land devoted to table olive production throughout the world is estimated at 1.18 million hectares from which 900,000 tonnes of olives were obtained on average over the period from 1987/88 to 1991/92. Overall consumption grew to 912,000 tonnes from 1990 to 1992. Exports rose to 207,000 tonnes from 1990 to 1992, with a resulting total carry-over at the end of the year of over 320,000 tonnes. This carry-over is rather larger than might be considered normal for a carry-over stock from one crop year to the next, usually estimated at consumption for three months.

The European Union, whose area is 410,000 hectares, accounts for approximately 47% of world production at over 427,000 tonnes on average for the period 1989/90 to 1992/93. Even so, real production might well be higher than these estimates for the reasons mentioned: producer family consumption and dual-purpose varieties.

With respect to foreign trade, the European Union is the leading world exporter at 120,000 tonnes (outside the EU) and the second importer, at a little over 30,000 tonnes, behind the United States. With consumption of

349,000 tonnes still rising in the period from 1990 to 1993, the European Union also occupies first place on the world scene as a consumer.

Spain, with 182,000 hectares under cultivation, is the leading world producer of table olives with 251,000 tonnes (1990-93 average). Domestic consumption is 106,000 tonnes so Spain is thus the leading world exporter with 130,000 tonnes (exports both inside and outside the European Union). There are 428 table olive processing companies comprising a host of family enterprises as well as modern enterprises and cooperatives which mostly concentrate on the export market.

The leading European consumer country, second only to the United States in world terms, is Italy with 137,000 tonnes. With an area under olives of 110,000 hectares, table olive production accounts for barely half of consumption which explains why Italy has to import large quantities of olives from Spain, Greece and Morocco. Italian processing firms usually obtain their supplies from outside the country, which is why Italian products are often consumed on a family level or are sold on local markets.

Greece is a major producer and exporter. With a cultivation area of 98,000 hectares, Greece produced 70,000 tonnes from 1990-93, of which it exported 40,000 tonnes (inside and outside the European Union). However total Greek consumption is only 28,000 tonnes. There are 78 table olive processing companies, 28 of which are cooperatives. Despite this, many farmers process their own olives.

Portugal has 92,000 hectares of land under table olives. Production is slightly ahead of domestic consumption, 20,000 tonnes by comparison with 19,000 tonnes, which enables Portugal to export small quantities (2-3,000 tonnes a year) of table olives (1989/93). It also started to import an average 5,000 tonnes of olives per year in 1989/90.

With 200,000 hectares of olive orchards and production of 110,000 tonnes (1990/92), Turkey is the second largest world producer of table olives. However its exports of only 8,000 tonnes are less than Morocco, due to high consumption of more than 100,000 tonnes.

Morocco, with 160,000 hectares and a production of only 80,000 tonnes, is nevertheless the second largest world exporter with more than 50,000 tonnes. Consumption is low in Morocco, just under 30,000 tonnes.

The United States has a table olive deficit since it produces a little over 100,000 tonnes in normal years while consuming almost 160,000 tonnes. The difference is covered by imports, and this country is world leader with an average of over 70,000 tonnes for the period 1990-92.

The whole of US production is obtained from only 12,400 hectares, indicating very high yields.

The table olive economy in Algeria is one of domestic self-supply since, with an area under olives of 27,000 hectares, the country produces enough for domestic consumption, of approximately 10,000 tonnes. Nevertheless, Algeria recently began exporting small quantities of table olives.

Syria is another major producer of table olives for the country's domestic market. With an area under olives of 160,000 hectares, the country produces and consumes some 60,000 tonnes.

Tunisia is a small exporter (2-3,000 tonnes) whose production and consumption of approximately 13,000 tonnes is obtained from 12,000 hectares under cultivation.

Other minor producers such as Argentina, Cyprus, Egypt, Jordan, Libya, Israel, the Lebanon and former Yugoslavia devote in all 200,000 hectares to olive growing for table purposes. As a group, these countries are very much in surplus since they produce 110,000 tonnes for a domestic consumption of only 70,000 tonnes.

There is not much potential for increasing consumption of table olives in non-producer countries since the product is largely unknown.

Production on the part of the main producer countries is also increasing, in step with the modernization of cultivation methods and larger orchards. For this type of product, occasional irrigation increases yields considerably.

EU ECONOMIC POLICY ON FATS

In view of the importance of the European Union olive oil economy within the world context, and the existence of a Common Agricultural Policy specifically for olive and vegetable oils, this section describes the main mechanisms applied by the EU in this sector.

Within the context of the Common Agricultural Policy, vegetable oils have traditionally been one of the food sectors with the most liberal trading rules. The exception was olive oil which, until 1 January 1995, was subject to a variable levy for EU imports. This has now been largely modified as a result of the Uruguay Round of the GATT agreements.

Trade has always been more liberal in the oil seed sector and, as a result of the trade agreements, all EU customs tariffs were lifted, for importing both raw materials and oils.

For this reason the EU oil seeds market is getting close to world market price levels with no frontier complications. Protection of the EU domestic oilseed production is not, therefore, carried out at the frontier but via a system of compensatory payments, namely hectare aid schemes for setting aside 15% of the area under cultivation.

The aid is received directly by growers and is restricted to a maximum area of 5,128,000 hectares, including the 15% area set aside, which corresponds to the average area under oilseed cultivation in the EU in the period 1989-90-91.

Up to 1992 prices in this sector were institutionalized by means of target and intervention prices with an aid scheme for processing which crushers obtained on acquiring EU seed. The system was changed as a result of the G.A.T.T. soya panel's negative verdict. The change of rules took place at the same time as the adoption of a similar system for cereals and protein crops.

In the case of oil seeds the aid is calculated in two stages. The unit aid per hectare is fixed provisionally as the difference between the expected price on the world oilseed market (163 Ecus/tonne) and the price desired in the EU, which is established on the basis of the price for cereals multiplied by a factor of 2.1 or the average EU coefficient between the yield of both types of production.

This difference, in turn, is multiplied by the regional average yield for oil seeds (or cereals, as the case may be, the choice being left up to each region), in order to obtain the total for the provisional compensatory amount.

The compensatory amount, in its final form, is established once the crop year is over, after the real price of oil seeds on the world market has been established. If the difference between the provisional calculation and the final calculation of this price does not exceed 8%, there is no adjustment of the compensatory amount. If the price difference is greater, an additional amount is paid. If the difference is less than this, the amount of aid is reduced accordingly.

In the case of olive oil the EU system is very different. There is a system of institutionalized prices, a system of aid to production and consumption, a set of rules for variable protection at the frontier and EU export refunds which will be substituted by a system of equivalent tariffs as from 1 January, 1995.

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Chapter 11

THE MARKETING OF OLIVE OIL AND OF TABLE OLIVES

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THE MARKETING OF OLIVE OIL AND OF TABLE OLIVES

IGINIO LAGIONI

There are several reasons why the subject of olive oil and table olive marketing need to be dealt with explicitly in this encyclopaedia.

The first reason is that olive oil and table olives are products that could potentially be consumed by the entire population of our planet. The fact that the inhabitants of some regions consume more of these products than others is due to historical reasons such as habit, whether or not olives are produced locally, industrial organisation, commercial distribution, competition from substitute products such as butter, animal and vegetable fats, etc.

The second reason has to do with where olives are grown, as olive oil is bound to be produced in regions where the olive is cultivated. This is obvious not only for historical reasons, but because the presence of olive cultivation has led to the establishment of mills and the subsequent distribution of oil, especially on local markets.

The third reason results from the first two and is the disproportionate distribution of olive oil and of table olives in the different countries of the world with consumption levels which differ widely from country to country.

The aims of this chapter on the marketing of olive oil and table olives are derived from the above considerations. They are to provide basic concepts and guidelines so that olive oil and table olives are consumed in the greatest possible number of countries and by the greatest possible number of people worldwide.

As has been shown in other chapters of this encyclopaedia, olive oil and table olives are suitable for human consumption at any latitude and at any age, so the purpose of this chapter is to explain how to best promote the consumption of olive oil and table olives in the greatest possible number of countries, not only in olive-growing regions.

After discussing certain basic conceptual precepts of marketing, the focus will shift to exploring the methodological aspects which must govern any approach to the marketing of the various types of olive oil and of table olives.

Then a few practical suggestions will be given to ensure that the marketing strategies and objectives outlined can be effectively implemented and attained.

In view of the international character of this encyclopaedia, this chapter must necessarily be general in scope. References to local situations are therefore avoided and discussion is geared more to marketing methodologies than to a description of current practices in olive oil and table olive marketing in the different countries.

THE MARKETING OF OLIVE OIL AND TABLE OLIVES

PROPOSAL FOR A DEFINITION

The following is a definition of the marketing of olive oil and table olives.

One or more companies or organised entities (consortia, associations, cooperatives, etc.) which produce or distribute olive oil and/or table olives engage in mar-

Mediterranean landscape (southern Italy) (Photograph by Gianluca Boetti).

keting when they set out to satisfy the tastes, expectations and wishes of the final consumers in order to meet their own objectives.

The higher the economic and cultural level of the potential consumers, the higher their requirements will be when comparing purchases.

Furthermore, the more developed the distribution system of a given country, the more likely it is that its inhabitants will be drawn to the points of sale where olive oil and table olives are on display for the public.

The following considerations therefore arise.

First of all, the attitudes and behaviour of consumers, as well as their habits, culture, purchasing power and tastes are decisive factors.

Where consumers have a certain degree of choice, they will have to decide whether or not to consume olive oil and table olives, what types to consume, and from which distributor to buy such products.

Companies or organisations must be capable of interpreting the tastes and habits of consumers if they are to ensure that the latter will select their products when offered for sale. Companies which adopt the approach outlined below are said to be «market-oriented.» Basically, the more a company centres on the consumer as the arbiter of his own purchasing choices, the more it is said to be «market-oriented.»

POSSIBLE CONSEQUENCES

The above considerations entail certain implications for both producers and distributors.

Firstly, the environment in which such companies operate must be taken into account. This environment is defined in macro and micro terms.

The macro-environment comprises the per capita income of the country, the level of employment, the degree of industrialisation, etc.

It also comprises the type of culture and social level of the inhabitants, their level of education, habits and traditions, the prevailing model of social intercourse, predominant religion, etc. Other factors include the country's degree of automation, the leading industrial sectors, the extent to which distribution is organised, etc.

The macro environment also comprises the legal system, regulations, quality control methods and, in general, the prevailing political structure.

To some extent, all of these components of the macro-environment can be said to influence the consumption of olive oil and of table olives. For example, countries with a high income per capita and a well-developed distribution system are undoubtedly in a better position to increase their consumption of olive oil and table olives. However, consumption of these products may be restricted by dietary habits based predominantly on animal and/or vegetable fats.

Furthermore, among populations with dietary habits which frequently use the olive as a garnish or aperitif (in Mediterranean countries olives are used in many dishes), it is reasonable to assume that a more market-oriented approach will produce good results in terms of sales and returns.

On the other hand, the micro-environment comprises the individual company or organisation, its competitors, the companies supplying the olives and the machinery for olive processing, the distribution system which in turn consists of traditional shops, organised distribution chains, wholesalers, importers and the final consumers.

The macro components, taken together with the micro components, constitute the marketing system.

And the marketing system for olive oil and table olives must be the basis for any marketing action.

No company or organised entity can afford not to take into account all the components of the marketing system.

Thus, for example, oil of poor quality cannot be sold in countries with strict food legislation.

Conversely, in countries with a higher income per capital, distribution may be more extensive, and prices may vary depending on the quality of the olive oil or table olives. Furthermore, competition will be more intense and the consumers better informed and more demanding, as they will have more alternatives to choose from.

From the above, it is clear that the marketing system and marketing actions are closely inter-connected: a company cannot market its goods unless it is familiar with the marketing system in which it is operating.

METHODOLOGY

Whereas the marketing of olive oil and table olives requires a knowledge of all the components of the marketing system in which a company operates, it is also true that tastes change, laws are improved, and the per capita income increases. In other words, to keep the marketing orientation in focus (or rather to place the environment outside the centre of any marketing action), an appropriate methodological approach is required. Such an approach is called the marketing planning process.

This process consists of all the marketing actions which must be implemented to ensure that consumers prefer to purchase «our» brand of oil over others, while achieving «our» profit objectives. The fact that such actions have to be planned in advance and incorporated into every company's marketing planning process is based on the marketing philosophy according to which the trends and developments of the external environment determine corporate decisions for the years to come. Therefore, we must establish today which types of olive oil and table olives should be placed on the market in one or two years and so forth.

MARKETING PLANNING PROCESS

Every company, whether in production or distribution, must adopt the marketing planning process as its methodology if it is to be market-oriented.

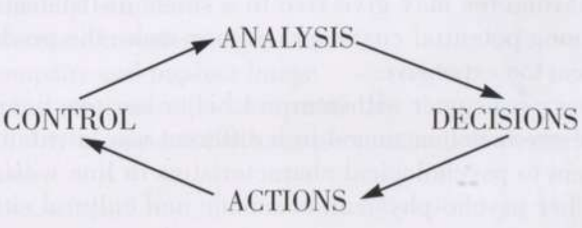
There is little point in offering olive oil and table olives at low prices in a country with low levels of consumption or in offering marvellous table olives in a country whose dietary habits do not include the consumption of olives.

The same can be said about advertising. It will have little effect if environmental conditions are such that products other than olive oil and table olives are preferred.

What is important is to plan in advance a series of efforts taking environmental conditions into account and using them as a basis for deciding which actions to undertake.

The marketing planning process consists of a number of steps which are distinct in conceptual terms, but integrated in practice.

These steps are described below.



The paragraphs which follow provide an analytical description of the steps depicted.

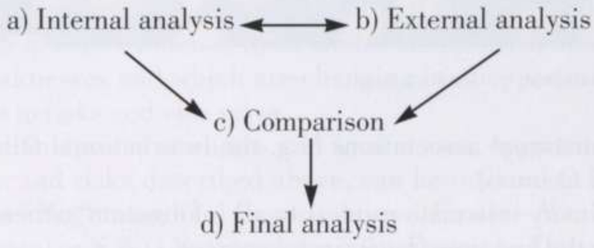
MARKETING ANALYSIS

The marketing analysis is the first step of any marketing planning process.

This step consists of taking all the components of the marketing system, both macro and micro, as sources of information from which a company can draw the details it needs to assess any external links, market opportunities, threats posed by the outside environment, etc.

To the external information is added internal information about the company itself, its managerial capacity, the quality of its human resources, the availability of other resources such as equipment, capital, quality control systems, etc.

The procedure for the analysis is based on the following diagram.

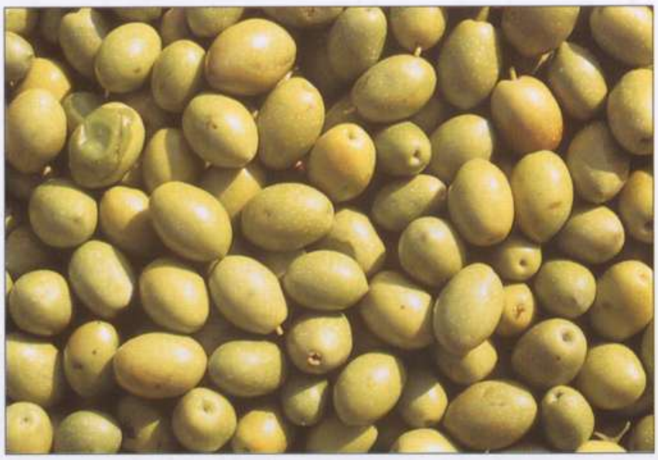


The internal analysis includes, amongst other data:
- Sales trends in recent years
- Client structure (number and size of sales channels, etc.)
- Range of types of oil sold (virgin, extra virgin, etc.)
- Sales trends for each type of oil
- Types of olives sold and relevant sales trends
- Prices per type of oil and olives
- Promotional activities and their effectiveness
- Advertising actions and their effect
- Consumer perception of products
- Areas in which we sell more and in which we sell less
- Positioning of «our» product on the market, or what is «our» company's share in total oil and olive consumption?
- What is «our» brand image among consumers?

The external analysis is based on two types of information, namely secondary and primary information.

Secondary information refers to all information available that has already been gathered elsewhere. Secondary information is obtained from such sources as newspapers, periodicals (specialised or otherwise), statistics yearbooks, catalogues, brochures, research studies by public institutions, etc.

Secondary sources can provide information on subjects such as imports and exports, the balance sheets of competing companies, legislative provisions on employment in the olive-growing sector or on hygienic conditions at the work place and tax systems. It also includes studies on trends within the olive-growing sector conducted in association with national and in-



(Photograph by Gianluca Boetti.)

ternational associations (e.g. the International Olive Oil Council).

Primary information refers to all information gathered for the first time from original sources.

Primary information includes information obtained directly through surveys, observations and systematic and casual record keeping. A few examples of primary information are: observation of the display of bottles of olive oil on supermarket shelves, competitors' prices, interviews among housewives to find out their purchasing attitudes and behaviour.

While internal information should be easy to locate inside one's own company, both secondary and primary information can be located only when acquired directly from the organisations that have it.

Typical organisations include trade associations, central statistics institutes, research institutes (in technology and marketing), specialised libraries or publishers. Research may also be entrusted to consultancy firms.

While secondary information is acquired as it is prepared, primary information may be obtained in a targeted manner through research projects carried out directly or through specialised external institutes.

Brief example of an analysis

Suppose that the firm Black & White intends to introduce a new type of olive oil on its national market.

The new oil is very light and is suitable for people of all ages, especially those suffering from liver complaints or digestive disorders, who prefer a bland diet.

The Black and White firm already distributes oils under its own label which range from the normal light type at an average price to an extra virgin oil from the first pressing.

Before doing anything else, the company will have to determine the potential for the new type of «health oil» in the market. Any attempt to launch the new product based simply on experience or intuition is bound to fail.

An in-depth analysis is therefore required.

Starting from the internal information, an initial analysis is conducted of the distribution channels used so far by Black & White to ascertain which would be the most suitable to distribute the new type of oil, preferably one with which the company has consolidated a long-standing business relationship.

It will also analyse its own sales force to establish which salespersons or promoters should be entrusted with bringing the new type of oil onto the market.

The analysis of secondary external information involves acquiring in-depth knowledge on the national distribution structure so as to find out what kind of pharmacies exist and what standards must be complied with in order to distribute this type of oil through pharmacies or drugstores.

Furthermore, it would be useful to know, from the secondary information, what medical literature has to say on the subject, whether import-export data on this particular type of oil are available, etc.

Turning now to primary information, Black and White must try to find out whether a potential market exists for this type of oil. This can be accomplished by conducting research with the following objectives:

- Potential number of persons who could benefit from the consumption of a light oil with medical properties;
- Opinions of potential consumers in comparative tastings of this type of oil as regards flavour, packaging, price and distribution channels.

It may turn out, for example, that distribution through pharmacies may give rise to a sense of frustration among potential customers or may make the product seem too expensive.

Every consumer will interpret his or her reactions to the products consumed in a different way, attributing them to psychological characteristics in line with his or her psycho-physical, economic and cultural situation.

Internal and external secondary information together with primary information provide the basis for the correct analysis of any marketing planning process.

Neither olive oil nor table olives can forego this process.

The example of Black and White is emblematic. The same procedure should be followed for any other situation.

This is the case, for example, for an advertising or promotional campaign in support of a brand of olive oil, modification of the range of oils currently sold, evaluation of competition on a specific olive oil market and charting of the marketing plan for the next year or two.

In short, no marketing decisions can be taken without adequate analysis support.

In addition to being fundamental to the decision-making process, such an analysis must moreover be formalized by being put down in writing, not only for the purpose of memorisation, but also to monitor relations between olive oil or table olive producers or distributors and their own market.

STRENGTHS AND WEAKNESSES, THREATS AND OPPORTUNITIES

The analysis and comparison of internal and external data must be used to pinpoint the weaknesses of the company in terms of internal inefficiency, but also the strengths and resources on which the company can rely.

Similarly, with regard to the external environment, the analysis must be used to identify market opportunities, such as the possibility of increasing the company's turnover by selling more olive oil and/or table olives, as well as possible threats, such as those posed by competing products and companies, etc. A chart of the main strengths and weaknesses, risks and opportunities for a typical olive oil or table olive producing or distribution company is given below.

Strengths and/or Weaknesses

- Sales force (direct salespersons, agents, distributors)
- Quality of the product
- Number of points of sale
- Financial situation
- Information system
- Company and product image
- Brand awareness (local or national)
- Quality of service (by salespersons and at points of sale)

Opportunities and/or risks

- Rising demand for particular types of olive oil and table olives
- Size of competing companies
- Efficiency of the sales force of competing companies
- New emerging competitors
- New tax regulations
- New payment regulations
- Possible drop in demand
- Products other than olive oil (e.g. groundnut oil or corn oil)
- Population trends
- Natural disasters (extreme weather conditions, fire, etc.)
- Closure of certain points of sale

All the strengths and weaknesses as well as risks and opportunities may change for the better or for the worse from time to time, depending on situations and circumstances.

For this reason, trends in the variables inside and outside the company must be monitored throughout the year to detect which of them are becoming strengths or weaknesses and which are changing from opportunities to risks and vice versa.

The analysis of strengths and weaknesses, opportunities and risks described above, can be referred to as S.O.F.W. (Strengths – Opportunities – Faults – Weaknesses) or S.W.O.R. (Strengths – Weaknesses – Opportunities – Risks).

A few examples will help illustrate the importance of S.O.F.W. or S.W.O.R. analyses.

Let us suppose that in a given country, Spain for example, 80% of the olive oil produced by the firm La Toledana is distributed by wholesalers established throughout the country.

Only 20% of the sales take place through three supermarket chains.

In view of the increasing importance of distribution through supermarket chains, La Toledana decides to adapt its own approach to the market by intensifying its sales through supermarket chains which do not yet distribute its range of olive oils.

This trend was pinpointed in articles in certain specialised periodicals on distribution problems and the relations between distribution and industry.

In the last three years, the impact of mass merchandising on the market has gone up by 20% with regard to traditional distribution (shops, sales representatives, etc.).

The internal analysis reveals that the sales force of La Toledana is not trained to deal with supermarkets. This constitutes a weakness. So far, dealings with the three chains carrying La Toledana's range of olive oils have been handled by the company's General Manager.

Henceforth, staff must be assigned exclusively to manage the marketing through the other supermarket chains.

Supermarkets are not just distributors because they conduct their own marketing for each point of sale, with shelf display, promotional actions, competitive prices, etc.

It is one thing to deal with wholesalers and another to deal with the purchasing managers of the various supermarket chains, which have by now become fully-fledged sales and distribution industries, with contractual capacities and turnover amounting to billions of dollars.

Consideration of this information – given new opportunities for sales through supermarkets on the one hand, and the lack of suitable staff within La Toledana to carry out trade marketing (i.e. marketing to organised distributors) on the other – leads the company to conduct an in-depth feasibility study of a marketing strategy geared directly to supermarket chains, and to avail itself of the necessary resources to implement such a new strategy.

Other weaknesses, in addition to the one detected above, may emerge. For example, the insufficient financial capacity of La Toledana, its insufficient knowledge of the purchasing behaviour of the different supermarket chains and of their relative capacity to absorb bottles of oil, purchasing terms, the required promotional support, etc.

Furthermore, threats may arise from other competing companies which are better established in that distribution channel, or barriers might be erected by competing companies already established in the new chain.

In the end, whereas a company must know how to satisfy the requirements of its target group in order to engage in (successful) marketing, it is also true that such requirements must be known and analysed before deciding on policies which could prove catastrophic in terms of resources deployed, missed opportunities and thus of economic results.

(Photograph by Gianluca Boetti.)

This obviously applies to the marketing of olive oil and/or table olives.

The more systematic the input and especially the gradual comparison of internal and external information as it becomes available through the marketing information system of the company, the more prompt and efficient the analysis process will be.

DECISION-MAKING

Decision-making comprises all the guidelines, actions and measures taken by an olive oil and/or table olive producing or distribution company in order to meet its corporate objectives.

It is clear that such directions, actions and measures can be charted and taken only on the basis of adequate analysis of consumption, consumers, distributors, competitors, etc. and on the relative internal capacity of the company to implement such decisions. The decision-making step will be all the more efficient if based on an adequate information support.

Decision-making comprises the:

a) definition of marketing objectives;
b) charting of an adequate marketing strategy;
c) design of a relevant programme of actions.

The more complete, thorough and formalised the analysis, the easier it will be to carry out points a) to c) above. It should be clearly set out on paper or on an IT medium.

This is the only possible way of completing the marketing planning process. Such a document will constitute the terms of reference not only for the commercial operations, but for all the company's operations.

DEFINITION OF MARKETING OBJECTIVES

The marketing objectives may vary depending on the results of the S.O.F.W. (or S.W.O.R.) analysis and on the intentions of the senior management.

Examples of possible marketing objectives include:

– 1.5% increase in the current market share
– 5% increase in profits for the following year
– Enhanced company image among traditional distribution channels
– Entry into two new supermarket chains the following year
– Improved profits from sales
– Increased volume of sales amongst existing distribution channels (in preference over new points of sale)

A few remarks are required.

Such objectives can be fixed once or more than once. It is important that they should be realistic and coherent. Thus, whereas the enhancement of the company's image among consumers may lead to an increase in the volume of sales and consequently of profits in channels where the brand is already present, the same may not occur if the main objective is to increase the volume of sales and to improve profitability.

Usually, an increase in the volume of sales is accompanied by lower profitability due to higher discounts granted to shops or points of sale purchasing larger quantities of oil.

It is also likely that a point of sale may engage in its own promotional activity to encourage consumers to buy more bottles of our brand of olive oil.

Furthermore, the objectives of the company may be qualitative and quantitative.

The former are objectives relating to image, brand awareness, customer loyalty, etc., while the latter are related to market share, turnover, profits, etc.

CHARTING THE MARKETING STRATEGY

Marketing strategy refers to all the marketing methods, policies, criteria or instruments which are decided on to attain the objectives indicated above.

The entire set of coordinated marketing policies constitute what is known as the marketing mix which, as the name implies, is a mix of policies and procedures deployed to optimise the company's relations with the markets.

The variables comprising the marketing mix are the:

– product
– price
– place (distribution)
– promotion (communication),

and are commonly referred to as the four Ps.

Let us examine each of these variables in turn.

Product

The product (or products), in our case olive oil and/or table olives, can be considered from the physical or the conceptual point of view.

The physical point of view consists of all the physical, organoleptic, taste and other such characteristics relative to the product as a physical entity.

From the physical point of view, the product (olive oil and table olives) consists essentially of the colour, taste, and levels of acidity. For table olives, it is also the size of the olives, the brine in which they are preserved, the packing, etc.

What counts in marketing is not so much the opinion of the producers of olive oil and table olives, but the opinion of the final consumers, and the success (or failure) of the olive oil and table olives placed on the market will depend on them.

The conceptual entity of the product is not so much what we think it is or should be, but what the consumer thinks it is.

Now if marketing means satisfying the needs and wishes of consumers, then the process boils down to putting on the market the products consumers prefer.

Consumers' opinion of products is shaped by many considerations: their cultural level, traditions, the information they have about different types of oil, their age, aesthetic tastes, income bracket, etc.

All these variables, together with other physical aspects and the importance consumers attach to them, are taken into account by consumers, each of whom forms his or her own idea or concept about the product.

The positioning of the product on the market is therefore determined by a combination of physical and apparent elements.

Depending on the market segment, or rather the type of consumers to which it is directed, the product (olive oil and/or table olives) takes on specific connotations on which consumers base their preferences.

So what type of product or products should companies put on the market in order to acquire the largest possible number of customers?

After carrying out the necessary market analysis, the parameters to be taken into account with a view to determining which olive oil or table olives to put on the market are as follows:

– For olive oil:
  · Physical and chemical characteristics (acidity, fats, etc.)
  · Taste
  · Colour and appearance (more or less green, more or less yellow, transparent, 'clean')
  · Container (bottle, tin, shape of container, convenient handling, quantity contained, container cap, pourability, external colour of the container, etc.)
  · Labelling (degree of communicability, legibility, messages contained, organoleptic specifications, etc.)
– For table olives:
  · Size and uniformity
  · With or without spices
  · Country of origin (Spain, Morocco, Italy, etc.)
  · Green or black
  · Packaged or loose
  · Type and shape of packaging (large or small, coloured or transparent jars, plastic sachets, etc.)
  · Closure and easy access to the product
  · Labelling (on the side, on top, etc.).

Seen this way, the product involves more variables and goes beyond the physical product itself.

As a result, the more the product corresponds to consumers' expectations, the more chances there are that marketing will be effective.

In the final analysis, olive oil and table olives should be conceived by the producers and distributors as a collection of parameters which combine to satisfy the consumers, on whom the success or failure of the product policy will depend.

Place (distribution)

As a marketing instrument, place (distribution) refers to all the actions which ensure that products arrive as close as possible to consumers, on the understanding that the easier the access to the products of their choice at the time they need them, the more chances there are that those products will be purchased and consumed.

As was the case for the product, two aspects of distribution are taken into consideration: physical distribution and the choice of channels through which products are made available for purchasing.

The problem of transport or transfer from the factory to the points of distribution and from there to the points of sale and the final consumer arises for both olive oil and table olives.

This is the physical aspect of distribution.

Without physical distribution, neither olive oil nor table olives can be purchased in large quantities and would turn rancid in their original storage facilities. For example, without physical distribution, there would be no trade in olive oil and table olives from Greece to Italy, from Italy to Germany, from Spain to Italy and to other European countries, from Italy to the United States and so on.

After collection on nets, the harvested olives are placed in a basket. (Photograph by Gianluca Boetti).

If the product is now widely consumed, this is undoubtedly thanks to modern, low-cost transport.

Nevertheless, in view of the fact that physical distribution necessarily entails costs, the marketing approach must be such that the organisation of physical distribution includes not only transport but also peripheral storage facilities, and maintenance and transport costs must be compatible with the product value, as defined above.

In addition to physical distribution, the other aspect that must be taken into account is the choice of channels through which final consumers will purchase oil and olives.

Distribution channels comprise wholesalers, traditional shops, travelling salesmen, sales organisations like cooperative chains, reselling consortia, supermarkets, etc.

Each country has its own distribution structure in line with its degree of organisation, its geographic features, political tendencies, etc.

The distribution channels may vary in length. For example, when oil and olives are transferred directly from the storage facilities of the producer to the central depot of a large mass merchandising chain or sold by telephone or through mail order catalogues, the channels are short.

More specifically, the transfer from producer to consumer is direct and immediate.

Conversely, when olive oil and/or table olives are exported from a producer country to the storage facilities of the importer, who in turn distributes to local wholesalers, who then distribute to small shops outside urban centres, the distribution channels are long.

Needless to say, the longer the channel the higher the costs which are added at every stage from one operator to the next, as some form of payment must be made to each along the way.

Furthermore, the more organised the distribution structure of a country, with a small number of traditional shops and a few major distribution chains, the greater the economies of scale for distribution. The number of physical transfers is much smaller and transport operations can be carried out for large quantities.

The choice of one channel over another depends on numerous factors: the size of the producer companies, the conceptual positioning of the various types of olive oils and/or olives placed on the market, the size of the market to be served, population dispersion, etc.

Prices

In macroeconomic terms, prices are considered fundamental for promoting trade both within a country and between different countries, but this is not the case when marketing specific products.

Though an important marketing instrument, price should be considered as just one of the variables of the marketing mix, on the same footing as the product, distribution and other variables.

There is little point in producing top-quality olive oil if the product is not distributed in such a way that consumers have access to it and are duly informed that it is available through the various channels of distribution via suitable means of communication.

The price of olive oil and table olives can be established by taking into account various preliminary conditions.

Firstly, if the company intends to pursue an aggressive policy of penetration, it will probably adopt lower prices than those of its competitors so as to induce consumers to buy its type of oil.

If this is the case, care must be taken not to give consumers the impression that the lower prices reflect inferior quality. Consequently, an aggressive policy geared to the competition is one thing; one geared to consumers is another.

Pricing policy also depends on the targeted profit margins, as well as on the channels of distribution chosen and on the market share the company hopes to gain.

In marketing, the pricing policy is basically adjusted to the market and market objectives, and then to profit.

Prices are set only partially in relation to costs: the latter are taken into consideration to establish the minimum profitability which the company should attain in order to survive and prosper in the long term.

Generally speaking, pricing policies may vary depending on the kind of relationship the company wants to establish with the market.

For example, if the company wants to operate at the top end of the market, with quality oils such as extra virgin, or very pure and light oils at low acidity levels and in very reassuring packaging, then it can price them high with very profitable margins.

It is virtually certain that this type of product policy will only lead to limited consumption by those categories of consumers with higher levels of income than the national average or by consumers who prefer quality oils even though the prices are higher than those of other types of oil available on the market.

Furthermore, if a prestige or quality image is added to the intrinsic quality of the oil, an image based on tradition, the consistent quality of the product, the importance of the point of sale (oils distributed through more exclusive shops are always more expensive but also of superior quality), then the relevant pricing policies must be commensurate and consistent with this prestige image.

It goes without saying that if the types of oil placed on the market do not have the quality requirements outlined above, competitive prices must be adopted differentiated by area, with special offers or promotional actions stressing the low prices rather than the characteristics and brand of the oil.

Promotion (communication)

Promotion (or communication) refers to all actions undertaken to publicise any aspect of the oil the company intends to introduce or to maintain on the market.

As already stated, communication is one of the instruments of marketing and therefore of the marketing strategy.

A distinction must be drawn between the instruments and methods of communication.

The instruments, or media, comprise all forms of visual and audiovisual communication such as advertising, promotion and personal selling.

Olive oil packs on display.

A basic requirement of communication, if it is to be efficient, is the capacity to provoke a reaction in the target group, usually consumers.

If this requirement is not met, no form of communication will have any effect on the purchasing behaviour of consumers regarding olive oil or table olives.

For these reasons, before undertaking any communication campaign with any type of media, a company must first analyse not only the purchasing behaviour of final consumers but also their views on the consumption of oil and table olives.

Such analyses can be used to evaluate consumption, frequency of purchase, distribution channels through which olive oil and table olives are purchased, and so on.

Consumers' opinions are analysed to evaluate the reasons for certain preferences, their expectations from the various types of oil and the different types of markets, the psychological reasons for choosing various types of food, etc.

Such analyses of opinions yield indispensable indications as to how to orient communication actions, while behaviour analyses yield indications on consumer trends.

A typical view is the perception consumers have as to whether oil is a healthy food.

If this is the prevailing view, then communication must also emphasise the healthy qualities of olive oil.

If, on the contrary, the prevailing interpretation sees the product as unhealthy, or reflects ignorance or scepticism, then communication should be geared to restoring credibility among potential consumers.

The combined analyses of the views and behaviour of consumers regarding the consumption of olive oil in general and of the various types of oil and the different markets yield useful indications on how to direct the communication actions.

As regards the media, the choice is almost infinite: it ranges from advertising on radio and television, to hoardings, specialised publications, posters at points of sale, mail order catalogues, and so on.

The promotional instruments which can be deployed for communication include all actions which stimulate the consumption of olive oil and olives directly by offering various types of advantages.

The most typical forms are free samples, special offers, discounts for quantity purchases, participation in a lottery, gadgets attached to oil packaging, and many others.

Personal selling covers the activity of every member of the company that, directly or indirectly, endeavours to increase sales.

Examples of personal selling include talks given by the General Manager of a company at associations or clubs for people interested in ergonomics and healthy eating, as well as door-to-door visits by the sales force.

THE MARKETING PLAN

Once the marketing policies have been defined, a decision will have to be made as to which of them should receive greater emphasis, or on whether to focus on prices, advertising or communication in the broad sense of the term, on the product, on channels of distribution, etc.

The different dosages of the various marketing elements constitute the marketing mix.

The marketing mix as a whole constitutes the marketing strategy, that is, the method which will be used to establish the relation between the company and selected market.

The choice of one marketing mix over another will entail various organisational implications and the input or output of various resources, both monetary and otherwise (personnel, transport, etc).

All these have to be formalised in a document called the Marketing Plan.

This document reflects, in quantitative and qualitative form, the summary of the marketing planning process described.

The marketing plan is useful for various reasons:

- It is a guiding instrument for managing and keeping under control developments in the company and its market;
- It exposes internal and external constraints to be taken into consideration when planning the company's marketing action;
- It promotes the coordination of the various functions of the company in accordance with the charted marketing direction;
- It ensures the possibility of measuring deviations from the charted course and taking corrective actions accordingly;
- It promotes the emergence of a corporate culture geared to marketing planning.

In the final analysis, the aim of the Marketing Plan is to optimise relations between the company and the market.

How to draw up the Marketing Plan

As with any document of a certain importance, the Marketing Plan must be drawn up in accordance with a certain structure.

A typical Marketing Plan structure is given below.

- Introduction and analysis

- Analysis of available resources
- S.O.F.W. evaluation
- Objectives and strategies
- Programmes of action
- Quantitative analysis

Introduction (or analysis)

This should include an evaluation of the results of the previous year or of the year coming to a close, revealing not only the main causes, but also the major macro variables which may influence or condition the course of the following and/or subsequent years.

Macro variables can include the state of the economy in general and possible influences on the consumption of various types of olive oil. Consumption of the finer, more expensive oils may obviously drop if the prevailing economic conditions in the country are such that consumers opt for oils of lower quality that are cheaper.

Another macro variable may be developments in the distribution infrastructure, an essential element for widespread consumption of olive oil and table olives.

Other useful indications may include consumer tendencies towards fine oils due to a heightened awareness about diets with less fats and acids.

Analysis of the resources available

The term «resources» here refers to both tangible (money, equipment, personnel, etc.), and intangible resources (quality of the personnel, level of services provided, punctuality of consignments, corporate or brand image among consumers, etc.).

This evaluates the available resources which in some way can influence or condition the future course of relations between the company and its markets.

S.O.F.W. evaluation

Analysis is conducted to measure the relations between the company and the market. The standard questions in such an analysis must include at least the following. To what extent are the types of oil and table olives we put on the market appreciated? How efficient is our distribution? Through which distribution channels do we work? What is our brand image? How do consumers perceive us in comparison with our main competitors? Have we seized the various opportunities offered by new consumer trends?

Each of these questions and many others must then be graded on a scale from 1 to 10 depending on the positive significance of each answer.

The fact that answers are subjective should not entail much risk of partiality. What counts is that each rating should be based on the relation between our company and the market.

Claiming that the quality of our oil is high is worth little: what counts is that consumers are aware of this and take it into account. Furthermore, our inability to keep our prices below a certain level is not a problem for the consumer but for our own company!

In democratic regimes, the success or failure of a product is dictated by the consumer, so it all boils down to knowing how to meet their expectations.

It is true, of course, that much consumption is stimulated by advertising in its various forms. This means that, to some extent, consumers are susceptible to the messages transmitted to them.

The various forms of communication aim at nothing more than revealing such susceptibilities.

Consumer needs are not created: they must pre-exist, albeit in latent or subconscious form.

Those who have always eaten vegetable or animal fats and gradually become consumers of olive oil have already a manifest nutritional need: the gradual shift to the consumption of olive oil has changed the way of satisfying this need, but the need already existed and was revealed.

Needs can nevertheless change as the cultural level rises and traditions lose their hold and become only symbolic references, in accordance with lifestyles and related dietary requirements, etc.

Objectives and strategies.

These constitute the decision-making proper of any marketing planning process.

This decision-making step consists of establishing today what must be done tomorrow.

This entails bearing in mind the analyses and data on the state of our company with regard to its consumers, competitors, distribution channels, etc.

In the end, the greater the amount of information at the disposal of our company, the more judicious the decisions taken will be.

Objectives are the results the company wishes to attain within a specific period of time. Such a period of time may range from a few months to a few years, depending on the type of products involved. For example, for olive oil and table olives, objectives may be quarterly, annual, or multi-annual, whereas for olive-growing, reasonable objectives can only be annual or multi-annual because of the diversity of the production cycles.

A few examples of objectives for olive oil and table olives may prove useful:

- Quarterly (half-yearly): recovery of 0.5% of sales, sales of x quintals of olives, etc.

- Yearly: increase revenues by x % gross of the volumes sold, penetrate in x sales outlets, acquire x % of the market share in areas a, b and c, improve the brand image of our oil, etc.
- Multi-year: penetrate distribution chains A, B and M with a 30/35% increase in the volume of sales over today's figures; or conquer markets C and F, etc.

All three of the above objectives are possible for olive oil and table olives.

In practice, quarterly and or half-yearly as well as yearly objectives are defined as operational objectives, because they are geared to obtaining results based on existing resources.

They are operational objectives therefore because they aim to improve results without changing the company's relation with the market, but simply by endeavouring to optimise it without distorting the arrangements of the company and thus its position with regard to the market.

Multi-year objectives are also called strategic objectives because they require not only long periods, but in some way aim to change the relation between the company and its markets, by deploying greater resources, in addition to or different from those already available.

Strategy refers to the entire set, in this case the mix, of methods adopted to achieve the objectives. The various methods deployed consist of the different possible mixes between product, price, distribution and communication mentioned earlier.

As already indicated, this selection constitutes the marketing mix.

The marketing strategy and the marketing mix are actually the same thing: both avail themselves of various marketing variables or instruments to optimise the company's relation with its market.

For the objectives to be attained and the strategy implemented successfully:

- they must be realistic and take into consideration current consumer tastes and the available resources of the company;
- specific timetables and actions on how to proceed must be indicated;
- they must be formalised, i.e. put down in writing and contained in a marketing plan document.

The programme of action

This comprises the series of actions to be taken in order to achieve the stated objectives and strategy on schedule and within the budget.

The programme of action must reflect the marketing policies and the basic philosophy of the company. It is also the step which makes it possible to determine to what extent the decisions taken have been successful or not among consumers.

The actions must be taken at the right time in a manner commensurate with the marketing objectives and strategy; consequently, they must be indicated in the most analytical and sequential manner possible.

Putting into effect a yearly operational marketing plan for any olive oil producing or distributing company requires a wide variety of foreseeable actions: these range from the hiring of one or more sales representatives, to the purchase of a delivery van, the training of sales representatives, the launching of an advertising campaign, one or more promotional actions and so on.

It is essential to execute the various actions in accordance with a schedule established in advance.

Consequently, the programme of action must be included in and constitute an integral part of the marketing plan.

Each action must be carried out within the specified time of commencement and completion, so as to occur at the right stage of market trends, and especially to ensure that the actions are coordinated with the objectives and other actions.

Suppose, for example, that in defining the marketing objectives and strategy it was decided to increase the company's penetration in one or two supermarket chains.

Suppose, furthermore, that agreements had been reached with the respective general management of these two supermarket chains to carry out a promotional action offering discounts based on the quantity purchased by each consumer.

It goes without saying that preparations for the promotional action must start in time, beginning with the design of the posters, the messages to be transmitted, packaging, etc. Above all, the company must ensure that sufficient quantities of bottles are constantly available on the shelves as the promotional campaign begins producing results in terms of more sales.

A form of reference for a generic programme of action is given below:

Actions	Week 1	Week 2	Week 3
Purchase of van			
Hiring sales representatives			
Launching promotional actions			
Interim review			
New lables			
TV commercials			

The same applies to all other actions, i.e. they must be coordinated with the other marketing objectives and, above all, with the other actions. There have been cases where lack of coordination between the different marketing actions inevitably produced disastrous effects in terms of sales results and the corporate image.

Quantitative analysis

Budget or Profit and Loss Account. For the marketing plan to be not only efficient for managerial purposes, but also to earn respect from all the company forces, it must conclude with a budget.

A budget is the formalisation, in quantitative terms, of everything to be done in the following year. In physical terms, a budget assumes the form of a proper preventive Profit and Loss Account. This account consists of two parts, one descriptive, the other quantitative.

The descriptive part comprises the following:

- Analysis of results: the results of the year which has come or is about to come to a close are briefly summarised to reveal variations from the previous budget. It goes without saying that if no budget was drawn up, the analysis will concentrate more on estimated profits or losses for the end of the year, as well as on the sales performance or the distribution of the company's olive oil on the market.

This first heading need not take more than two pages, or three at most.

- S.O.F.W. analysis. As already indicated above, this analysis is used to determine the extent to which our company is capable of increasing its penetration of the market, through an evaluation of its strengths and weaknesses.

The internal strengths and weaknesses of our company, as well its capacity to conduct marketing for its own line of olive oil and table olives, must be compared to the opportunities offered in the external environment, i.e. the market, as well as any external threats.

The analysis of these four aspects, abbreviated as S.O.F.W. (Strengths, Opportunities, Faults, Weaknesses) should be as concise as the previous one and perhaps even more so. It is actually the result of more extensive and more in-depth analyses which must be carried out throughout the course of the year, or when drawing up the yearly marketing plan.

They must therefore appear as the culmination of an analytical process inside and outside the company which reveals the parameters on which the operational phase should be carried out.

- Definition of objectives. The more in-depth the S.O.F.W. analysis, the easier it will be to define the objectives, by making it possible to define volume, prices, returns, levels of penetration in the market, etc., to be attained in the next year.

The objectives must necessarily be expressed in quantitative terms: volumes (litres, kilograms, quintals, etc.), returns and costs or expenses.

The reason is simple: volume, returns, costs and expenses are typical items in any Profit and Loss Account, and therefore of the Profit and Loss Account of any olive oil producing or distributing company.

The actions will have to be related to the Profit and Loss Account in that their foreseeable costs have to be quantified.

It is then time to draw up the Profit and Loss account.

A typical general layout for the Profit and Loss account of an olive oil producing company is given below. The same form applies to a company which distributes table olives.

Profit and loss

a) Quantities (volume of sales in litres, kg., etc.)
b) Unit prices
c) Gross proceeds (a x b gross discounts/quantity)
d) Discounts and deductions (to be subtracted from 2).
e) Net proceeds
f) Direct costs
   – raw materials (olives for pressing)
   – energy
   – direct manual labour (for oil production)
g) Gross contribution margin (e. minus f.)

A display of regional Italian olive oils.

h) Promotional expenses (directly related to the volume of oil sold during the year)
i) Commissions (usually granted to agents and/or representatives)
j) Advertising expenses (for the appropriate part of the year)
k) Transport costs (for transport from the production centre to the distribution centres)
l) Net contribution margin (g. minus h. + i. + j. + k.).
m) Expenditure on personnel
n) Administrative expenses
o) General expenses
p) Depreciation
q) Rent
r) Sum of all the above
s) Gross profit (before tax)

A few remarks are in order here.

First of all, it should be pointed out that the items indicated in the Profit and Loss Account form outlined above may be named differently in different countries but in essence they are the same.

The important thing is that the Profit and Loss Account should be structured in such a way as to make it possible to identify an initial group of items of expenses proportional (or nearly so) to the turnover and net revenue (in the form given above the expenses contained in items f)., h)., i)., j. and k).).

This will indicate to what extent revenue from the sale of olive oil and table olives will be profitable and, more specifically, the extent to which such margins cover the fixed costs or expenses under items n)., o).,p)., q)., and r).

Furthermore, the structure of the Profit and Loss Account outlined above makes it possible to calculate the point of equilibrium of what has been said previously (see the section on Prices).

In this instance, the calculation can be made as follows.

For the sake of simplicity, items which represent proportional costs or expenses should be added up and their unit value calculated. This unit cost is then compared with the net unit return.

At this point, the break-even point formula is as follows:

$$\text{Quantity to be sold (unknown)} = \frac{\textbf{Total fixed costs}}{\textbf{Nur - Nuc}}$$

whith: **Nur** = Net unit return
Nuc = Net unit cost

The quantity to be produced and sold to balance the total costs (fixed plus variable) with the total returns, is obtained from the quotient between the numerator and the denominator of the fraction indicated above.

An example can illustrate this better.

Let us take a company which usually invoices about US $ 100 million a year.

Now suppose this company has fixed costs (not related to the volume of oil sold) of US $ 15 million a year; furthermore, that the unit cost for producing and distributing the oil to the various points of sale, at the current production capacity, is $ US 4 a litre, and that the product is sold to the various points of sale at an average price of US $ 6. What will be the break-even point, or rather what will be the volume of oil (in litres) which our company will have to sell to cover all the costs incurred?

The calculation will be as follows:

$$\text{q (unknown)} = \frac{15{,}000{,}000}{6 - 4} = 7.5 \text{ million bottles}$$

This simple example shows how it is possible to evaluate in advance the number of bottles of our oil that must be sold (or rather, which consumers have to buy) in order to cover at least all the company's costs.

Whereas both the average net unit return and the direct unit cost for each bottle require considerable simplifications in terms of average values, the calculation of the break-even point remains valid.

For a more empirical, as well as more direct calculation, we can compare the absolute value of the net contribution margin with the sum of the successive fixed costs. The result may be zero, positive or negative.

Analysis of the three situations makes it possible to establish, a priori, the extent to which the contribution margin – the net margin more than the gross – will cover total fixed costs.

It is therefore possible to carry out marketing actions to encourage consumers to buy increasing quantities of bottles of olive oil and/or table olives of our company; or to persuade them to buy the same volume at higher prices, enabling us to apply higher contribution margins.

In both hypotheses, with fixed costs being the same, the possibility of covering them would increase thanks to the higher contribution margins.

All this can occur if the marketing plan described above is put into action.

MARKETING CONTROL

Any activities involved in a marketing planning process have to be complemented by means of a control process and this also applies to marketing for olive oil and table olives.

Manual harvesting of olives. (Photograph by Gianluca Boetti).

There are various reasons:

- A control process makes it possible to determine whether any decisions taken have actually been put into practice or whether there have been delays, omissions or variations.
  By delaying for just one month the engagement of a salesperson or department head or the purchase of a transport vehicle or by not carrying out at the right time promotional or communication activities, meeting the financial targets covered by the budget may become impossible.
- It also provides the necessary elements to determine whether the economic targets are being met or not.
  Certain of the decisions taken when defining the marketing objectives and strategies may not be giving the desired results for any of several reasons: because the competition has been taking particularly aggressive marketing action, because the communication actions taken have not given the expected results, etc.
  It is not sufficient to draw up a careful marketing plan; its results have to be carefully monitored.
  Marketing control should be understood more as an integral and indispensable part of the marketing planning process rather than as an inquisitorial instrument for the person carrying out the marketing plan.
- It also makes it possible to intervene immediately to correct any actions that are seen to not be as efficient as planned or to intensify any actions that are proving to be particularly effective. This occurs for example when a certain product is launched or promoted in a supermarket, when there is a decision to increase our company's penetration in a new market area, etc.

Marketing control must be carried out methodically.

There are three possible approaches – after, during and before.

The first is very similar to traditional management control. In practice, it is a matter of finding out the results at the end of each month, analysing them and pointing out any deviations from the targets.

Then the causes of such deviations must be determined and any corrective measures studied that could be added to the programme of action set up at the start of the year.

This approach, while valid on an administrative level, is not so useful from the operative marketing point of view: any corrective action would be taken well after the deviation was noticed and therefore very late with respect to the cause of the deviation.

A better approach is to note results on a day-to-day basis and, using a chart, to compare the results with the budget data and, whenever there are significant deviations, to try to intervene immediately.

An approach that is even more efficient though sophisticated is to face marketing control in a preventive way. This involves observing the progress of results and any deviations from the budget but especially keeping under control any internal and external variables that might influence results in the short term by constant preventive monitoring at regular intervals (weekly, monthly, etc.).

The mechanism is as follows: at the end of each month, the latest results are observed and deviations and their causes are analysed.

At the same time, in the meeting with the commercial managers (area heads, inspectors, product managers, etc.), the aim should be not just to determine which corrective measures should be set up but also to identify possible variables (internal and external) that might influence sales trends either positively or negatively.

Examples of such critical internal variables might be the resignation of one or more salespersons, defective batches of oil, depletion of stocks, problems with production, etc.

Critical external variables might include the opening or closure of an important road, entry into the market

An Italian grocer's shop.

(Photograph by Gianluca Boetti.)

of a new competitor, modification of a competitor's marketing strategy, etc.

The third approach is undoubtedly the most modern provided that there is a computer-aided information system that makes it possible to note both budget and final data and that any decisions taken to adapt to predictions for the next month or two are recorded on the computer systems.

Basically, the aim must be to set up an operative marketing control system that will make it possible not just to analyse results as they appear, but also to keep under control the critical variables that might affect trends in sales of olive oil and table olives during the course of the year and that were not foreseeable when the marketing plan and its budget were drawn up.

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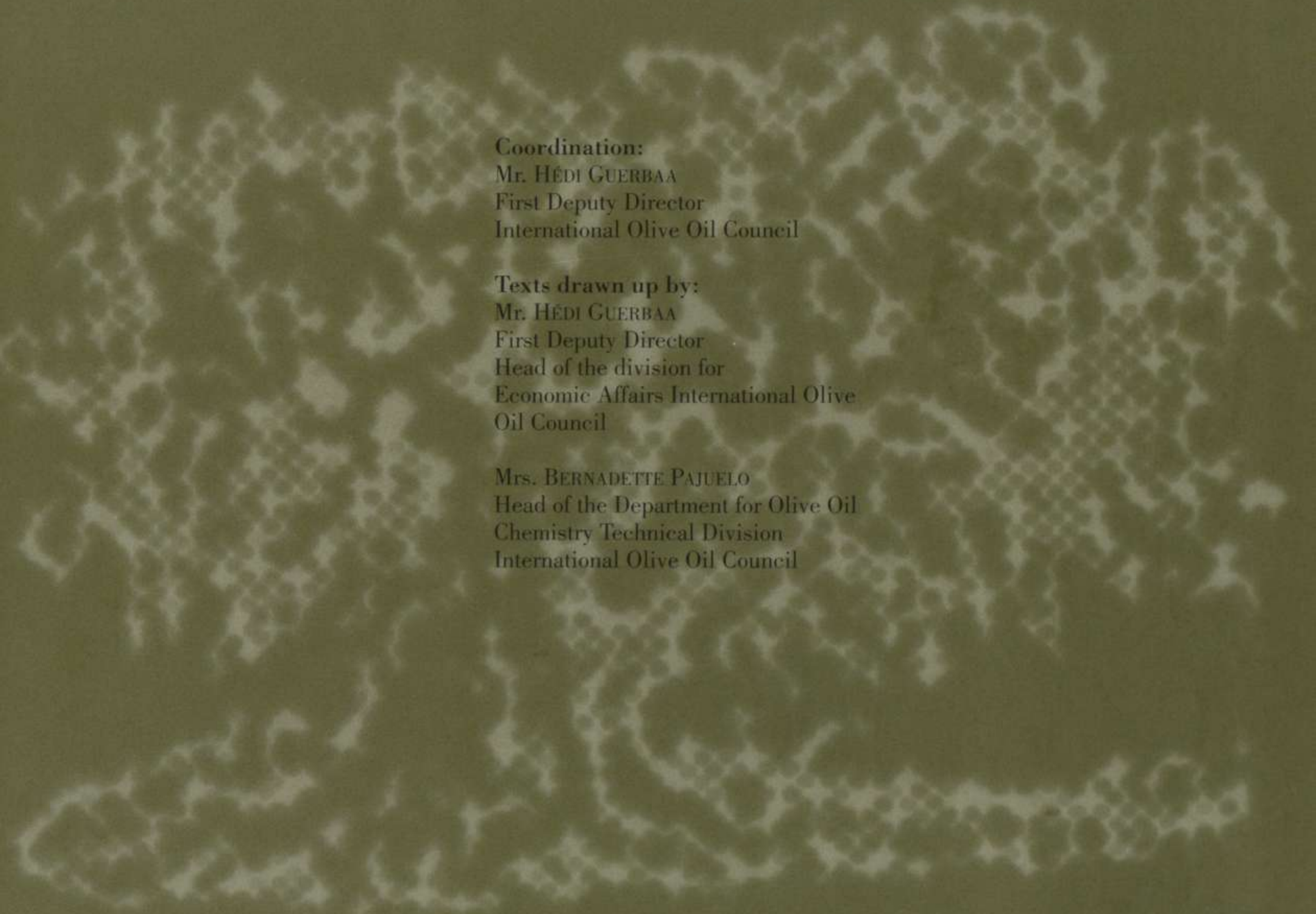
Chapter 12

NATIONAL LEGISLATION AND POLICIES IN THE OLIVE SECTOR



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NATIONAL LEGISLATION AND POLICIES IN THE OLIVE SECTOR

EXECUTIVE SECRETARIAT
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OIL COUNCIL

Although olive oil has only a small share (around 15%) of the world market for liquid vegetable oils, it is of great socio-economic importance. Olive farming provides a living for over 2 million families in generally poor agricultural areas which, in most cases, are not suitable for other crops. In addition, olive oil and table olives are basic to the diet of many nations, especially in the Mediterranean basin countries, the origin of 98% of world production. It is, therefore, most important to protect and promote olive cultivation with a view to securing the future of the many families who depend on it.

In order to find solutions to the international problems of the olive sector, the International Agreement on Olive Oil and Table Olives (subsequently called the Agreement) was reached in its first version in 1956. The International Olive Oil Council is the organisation responsible for administering this Agreement and for implementing a series of measures to promote international cooperation, the modernisation of olive cultivation and olive oil processing through the transfer of technology, olive oil consumption, and the expansion and standardisation of international trade.

This chapter aims to provide a better insight into the policies followed by the major olive-growing countries in the areas of olive oil production, processing and marketing, in the hope that, the greater the knowledge of the general and individual objectives which are behind these policies and of the methods used to put them into practice, the easier it will be to achieve effective cooperation and integrated development of olive-growing beyond national frontiers.

The different countries all have to face the same type of problems and, although their objectives are similar, the solutions applied are not necessarily the same. The economic and social requirements of each country and of the production situation in them must be taken into account when building up a policy for the olive sector. Based on these considerations, the olive producer countries fall roughly into two groups:

- Countries with high levels of production that generally have a well-structured olive policy in which the State is actively involved. In some cases public sector intervention is so great that the sector turns into a State monopoly or quasi-monopoly.
- Countries with lower levels of production that generally have a less well-developed olive policy although they are equally concerned about the problems existing in olive cultivation and olive oil trade.

All policies for the olive sector inevitably cover three points: production, processing and trade.

In the field of production, one of the main problems is that the outdated cultivation techniques still widely used tend to give low yields. In addition, irregular bearing patterns give rise to fluctuations in production, difficulties in supplying markets, unstable prices and unpredictable income for olive growers. The policies of the different countries therefore always centre on improving the productivity and profitability of olive cultivation.

In order to increase production, the methods applied by the authorities are usually in the areas of genetic improvement, pest control, full mechanisation of cultural care operations and training of olive growers.

It is also important that olive-growing be profitable for growers because, if they do not obtain a fair income, they are likely to abandon this activity. Since it is difficult to find suitable alternatives, this results in the land being left unproductive and in farmers leaving the country to settle in the cities.

The problem is frequently resolved by granting state aid to growers in order to give them a reasonable income but such aid varies greatly from one country to another. A frequently-used measure is to guarantee a minimum purchase price allowing the grower to receive at least sufficient income to cover his basic needs.

In the field of processing, the main objective is to improve industrialisation by replacing traditional mills with modern ones thus making better use of crops and achieving an end product of better quality. Here too the most common method is the granting of state aid.

In the fields of consumption and trade, the irregular, cyclical nature of olive crops makes it difficult to keep prices stable and ensure constant market supply. It is also necessary to compete with other vegetable oils which are generally cheaper.

To lessen the impact of irregular bearing, in addition to making efforts to improve cultural care techniques, countries sometimes set aside buffer stocks to avoid shortages.

The measures taken to compete on the market vary from country to country.

In countries with low levels of olive oil production, trade strategies are not very well-developed because, since the supply of fats and oils is poor, olive oil tends to be consumed by producers themselves or is sold locally.

The problem is greater in countries with higher levels of production in which competition with other vegetable oils is greater. Here the aim is to make olive oil more attractive to the consumer.

- Firstly, prices have to be lowered to reduce the difference between olive oil and other vegetable oils. Over recent years the methods applied have been changing and, whereas formerly state aid was granted to encourage consumption, at present efforts are being made to cheapen the cost of production by using more modern techniques to improve productivity.
- Secondly, research is being intensified and the beneficial effects of olive oil consumption are receiving publicity. Efforts are also being made to improve quality, to reduce fraud and to limit unfair competition.

In the case of foreign trade in olive oil, a distinction must be made between countries with high levels of production and those producing small quantities of olive oil.

In the latter, the quantity of other edible vegetable oils available also tends to be insufficient to meet domestic needs and imports are necessary.

Countries with a high level of production usually export a large proportion of their olive oil production and therefore have a clear policy promoting foreign trade. In many cases, import taxes or quotas are also established to protect olive oil against competing products.

In short, some of the main challenges facing the different olive-producing countries are to increase production to cover shortfalls in the fats and oils market, to achieve a fair income for olive growers without raising prices to uncompetitive levels, to improve olive oil quality and to increase international trade.

If these objectives are to be attained, it is very important to coordinate the actions taken by the different countries. This is one of the aims of the Agreement and of the international policy defined within it and special importance needs to be placed on actions relating to foreign trade and regulation of the olive oil sector, and to the removal of obstacles to international trade.

MEMBERS OF THE INTERNATIONAL OLIVE OIL COUNCIL

EUROPEAN COMMUNITY (EC)

General information

The Mediterranean basin has the highest world levels of production and consumption of olive oil. However, it is the EC that stands as the world's main producer although only five of its fifteen Members (France, Greece, Italy, Portugal and Spain) are large producers.

Principles of the Common Agricultural Policy

The entry into force of the Treaty of Rome on 25 March 1957 led to the adoption by the Member States of a number of common policies (agriculture, trade and transport) which meant that the national policies were replaced by policies drawn up by the Community. The Common Agricultural Policy (CAP) was from the start the most advanced.

With a view to fulfilling the objectives of the Treaty of Rome, article 40 of the Treaty makes provision for the creation of a Common Organisation of agricultural Markets (COM) under which each product or sector is regulated by a basic regulation and a series of additional regulations which are adapted and amended as necessary according to the specific characteristics of each sector.

The Basic Regulation of the COM relating to the fats and oils sector is Regulation no.136/66/EEC of the Council of 22 September 1966. This Regulation lays down the following general principles with respect to olive cultivation.

1. Olive cultivation and olive oil production are of special economic importance in certain regions of

the Community and are often an essential source of income for a large proportion of the population. Furthermore, olive oil is the most important source of fats for large categories of consumers.

2. The marketing of crops must ensure producers a fair income, the level of which may be determined by a production target price for olive oil. The difference between these prices and prices acceptable to the consumer represents the subsidy which should be granted to attain the desired objective.
3. Consumers generally prefer olive oil to other products of a similar kind and it may therefore be sold at a higher price. Prices for competing products being taken into account, it is therefore possible to determine a market target price that will provide the producer with a large proportion of the requisite income and aid in the form of receipts from sales.
4. Since the market target price for olive oil cannot attain its objective unless the price actually ruling on the market is as close as possible to the market target price, stabilising mechanisms should be provided in producer Member States and at the Community frontier.
5. The desired stability may be obtained within the Community by making it possible in production areas for olive oil to be offered to competent agencies of the Member State at the intervention price. Moreover, in order to ensure that there is a constant balance between supply and demand and to counteract the effects of fluctuations in production, provision should be made for the possibility of entrusting intervention agencies with the task of forming a buffer stock.
6. In order to stabilise the Community market at the desired level, notably by ensuring that fluctuations in world market prices do not affect prices within the Community, provision should be made for charging an import levy corresponding to the difference between the threshold price derived from the target market price (later called representative price) and the CIF prices ruling on the world market (cost, insurance and freight). In order to ensure that protection is complete and consistent, olive pomace, other residues resulting from the extraction of olives and oil olives are also subject to a system having the same effect.
7. In the case of olive oil used in the processing of preserved fish and vegetables, the levy must be suspended or a refund granted to enable manufacturers to meet competition from similar products processed with oil bought at world market prices.
8. Export refunds may be considered in cases of olive oil exports to third countries.
9. Protective measures may be required to ensure supplies of olive oil to consumers in Community countries in the case of an imbalance in the ratio between olive oil prices on the world market and those within the Community or when olive oil imports or exports in certain circumstances lead to market disturbances.
10. The common organisation of the market in fats and oils must also take due account of the objectives set out in Articles 39 and 110 of the Treaty of Rome.

Since the founding of the Community, new needs and consequently new objectives have arisen. These include:

1. The need to improve the situation of agriculture and the general economic conditions of the Mediterranean area. This objective goes beyond the Community frontiers and a policy of trade and association agreements has been applied with most of the Mediterranean countries.
2. The need to maintain employment in the agricultural sector at acceptable social and income levels. Measures include the creation of olive oil producer groups and federations of such groups, the rules for which were laid down in Council Regulation (CEE) no. 1360/78 of 19 June 1978.
3. The need to put a stop to the drop in consumption of olive oil within the Community. Aid towards consumption was introduced with this aim by Council Regulation (EEC) no. 1562/78 of 29 June 1978, which amended Regulation 136/66/EEC.

Only six countries initially signed the Treaty of Rome on 25 March 1957 (Belgium, France, Germany, Italy, Luxembourg and the Netherlands) and, of these, only two were large olive oil producers - France and Italy. But the EC has since been extended on several occasions: first, by the Accession Agreements signed by Denmark, Great Britain and Ireland on 22 January 1972 and which entered in force on 1 January 1973 and, later, with the accession of three large olive-producing countries: Greece, which signed its membership on 28 May 1979 and gained full entry on 1 January 1981, and Spain and Portugal whose Acts of Accession became operational on 1 January 1986. The enlargement of the EC with the entry of these countries did not give rise to any change in the abovementioned principles, but did make it necessary to intensify efforts to fulfil them.

While not affecting the olive oil sector, the reforms made to the Common Agricultural Policy in 1992 affected the regulations relating to colza, rape and sunflower seeds and soya beans. The whole sector, however, may be affected by the negotiations of the Uruguay Round of the GATT which ended on 15 December 1993. It will be necessary to change much of the philosophy behind the common olive oil policy because variable frontier protection is to be replaced by a single system of fixed customs tariffs.

In the long term, the preferential agreements between the EC and a large number of Mediterranean countries creating special arrangements for olive oil trade will have to be changed.

Basis for the common agricultural policy for the olive oil sector

Council Regulation no.136/66/EEC dated 22 September 1966 created a Common Organisation of the market for fats and oils. This and its many implementing regulations outline the basis of the community policy in this sector which is as follows:

1. One specific price system

The above-mentioned Regulation no. 136/66/EEC establishing a COM in fats and oils introduced a price system whereby a production target price, a representative market price, an intervention price and a threshold price are set annually for every member State. These prices are laid down for wholesale dealings for a standard quality of olive oil and must be set early enough at the start of each crop year.

The production target price is a target price that is fixed at a level to ensure that farmers receive a fair income taking into account the need to maintain the necessary volume of production in the Community. It is the same as the intervention price plus production aid and transport costs from the production areas to the consumer markets as well as a profit margin. It is fixed annually before 1 August for the following year's trade.

The intervention price, which guarantees that producers will be able to sell their product at a price as near as possible to the market representative prices, is the price paid by the intervention agencies for oils of the standard quality offered to them. This price is the same as the target producer price but after deducting production aid. The amount must take into account market variations and transport costs from the production areas to the consumer markets. This price is fixed before 1 August for the following year's trade.

The representative market price is fixed at a level which enables olive oil to be sold normally taking into account the prices of competing products and especially their expected market trends.

The threshold or entry price is set so that the selling price of the imported product stands, for a point on the Community frontier, at the level of the representative market price, taking into account the effect of measures relating to consumption aid.

The production target price and the intervention price remain unchanged throughout the crop year whereas the representative market price and the entry price may be altered by the Commission.

2. Measures relating to production

2.1 Intervention agencies

According to the Basic Regulation (136/66/EEC), which was last modified on this point by Council Regulation (EC) no. 3179/93, the intervention agencies appointed by the producer Member States are under the obligation to buy in each crop year from July to October any olive oil produced within the Community and offered to them by producers or by producer groups and associations recognised pursuant to Council Regulation (EEC) No.1360/78. The buying-in price shall be the intervention price.

2.2 Aid towards production

The Basic Regulation (136/66/EEC), which was last modified on this point by Regulation (EEC) no. 2046/92, stipulates that each year the Council has to fix before 1 August a uniform sum for production aid with a view to establishing a fair income for producers. The Council also fixes the maximum quantity of olive oil to which the aid fixed for each crop year can be applied. If the actual production within one crop year exceeds the maximum guaranteed quantity for that year, unit aid is reduced by applying a coefficient equal to the quotient between the maximum guaranteed quantity and the actual quantity. If actual production in one crop year does not exceed the maximum guaranteed quantity fixed for that year, the difference is carried over so that the maximum guaranteed quantity is obtained for the following crop year. This method takes into account the phenomenon of alternate bearing that is typical of olive production. Penalties in production aid are not applied to «small olive farmers». Since the introduction of the system of budgetary stabilisers in the olive oil sector, the maximum guaranteed quantity for production aid has been one million three hundred and fifty thousand tonnes (1,350,000 t).

Procedures for obtaining aid vary depending on whether producers are members of recognised producer organisations or not. Aid can be fixed at a special level for those olive growers whose average production of olive oil does not reach 500 Kg per crop year.

2.3 Producer organisations

The Council has introduced a scheme to encourage the creation of groups of producers. One of the products benefiting from these regulations is olive oil. These distinguish between two types of organisation: producer organisations (large groups which are capable of channelling olive oil production aid) and unions of producer organisations (made up of producer organisations from different economic areas).

In the specific case of olive oil, producer organisations and unions are currently governed by the Basic Regulation no. 136/66/EEC, which is implemented in Council Regulation (EEC) no. 2261/84 of 17 July 1984.

2.4 Compilation of an olive file in the olive-producer Member States

Under the terms of Council Regulation (EEC) no. 157/75 of 21 January 1975, which was amended by Council Regulation (EEC) no. 3453/80 of 22 December 1980, the Member States producing olive oil have to compile an olive file for all the olive farms within their territory. The aim of this file is to obtain the necessary data to determine the olive assets and the potential production of olives and olive oil within the Community as well as to facilitate the functioning of the Community aid scheme for olive oil.

2.5 Quality improvement of olive products

Quality improvement of olive products continues to be one of the aims of the Community olive oil policy. The main actions proposed to improve quality are control of the olive fly (Dacus oleae) and other pests, improved techniques for olive farming and harvesting, improved olive storage and processing as well as storage of the resulting oil, technical assistance for olive growers and millers during oil extraction, the installation and/or administration of tasting laboratories to test the organoleptic characteristics of virgin olive oils, the installation and/or administration on regional or provincial levels of laboratories to evaluate the physical and chemical characteristics of olive oils and collaboration with organisations specialising in improving olive oil quality.

2.6 Common research and coordination programmes

Taking into account, amongst other factors, the low level of development of many regions of the Community, especially in the Mediterranean, the EC Council adopted Decision no. 78/902/EEC of 30 October 1978 setting up common research programmes and research coordination programmes with a view to attaining socio-structural aims, the elimination of obstacles to trade in agricultural products within the Community and efficient production both of olive oil and other products. These programmes were set up for five years starting on 1 January 1979. They were discontinued but are expected to be implemented once more in the near future.

3. Olive oil trade and consumption

The Basic Council Regulation no. 136/66/EEC and its various implementing regulations also cover in detail trade and consumption of olive oil. The following are the most important aspects of the Community policy for olive oil in this area.

3.1 Olive oil storage

The Basic Regulation no. 136/66/EEC stipulates that in order to minimise the consequences of irregular harvests on the balance between supply and demand and thus stabilise consumer prices, the Council may decide to constitute buffer stocks of olive oil through the intervention agencies and may determine the conditions for the creation, administration and trade of such stocks. It is also possible to draw up storage contracts with the recognised organisations or associations for the olive oil traded by them.

3.2 Olive oil sales by intervention organisations

The Basic Regulation no. 136/66/EEC lays down that the intervention agencies sell the olive oil they buy in the Community under such conditions as to not disturb the market during the production stage. Commission Regulation (EEC) no. 2960/77 of 23 December 1977, which was last amended by Regulation (EEC) no. 3818/85 of 30 December 1985, lays down the procedure for the sale of olive oil held by intervention agencies. As a rule, sales shall be effected by means of tenders. Security must be furnished with the offers.

3.3 Aid towards consumption

Consumption aid was first introduced in April 1979 to increase the competitiveness of olive oil with respect to other cheaper oils.

The Basic Regulation no. 136/66/EEC, which was last modified on this point by Regulation (EEC) no. 2046/92, stipulates that this aid is granted to packing companies that satisfy the conditions required under Commission Regulation (EEC) no. 2677/85 of 24 September 1985, which was last amended by Commission Regulation (EEC) no. 643/93 of 19 March 1993.

It covers olive oil produced and traded within the EC and canned or bottled by them. Eligibility for aid is obtained as soon as the oil leaves the premises of the packing company. The unit sum of aid for olive oil is that obtained by deducting production aid and the representative market price from the production target price.

3.4 Refunds granted for olive oil used in the preparation of certain preserved foods

Council Regulation no. 136/66/EEC stipulates that olive oil to be used in the processing of preserved foods shall benefit from a system of production refunds or from full or partial suspension of the import levy. Council Regulations (EEC) no. 591/79 of 23 March 1979 and no. 2903/89 of 25 September 1989 lay down the general conditions governing these refunds. According to these Regulations, the Commission fixes the refund every two months, taking into account the sum of consumption aid for olive oil produced in the EC.

3.5 Labelling, presentation and advertising of food products for the final consumer

One of the objectives that the EC sets out to achieve is free circulation of goods between the Member States. It is therefore necessary to remove both legal and physical obstacles in the way of this objective.

The Council issues directives to help to remove obstacles gradually, that is, rulings by Community bodies outlining common objectives. Each Member State can then establish its own regulations, provided they are based on the directives and aimed at achieving these objectives. Internal legislation is thus harmonised without countries losing their capacity for self-regulation.

With respect to olive oil, attention should be drawn to Council Directive 75/106/EEC of 19 December 1974, which was last amended on 21 December 1989, concerning the conditions for the retail presentation of liquids in pre-prepared, sealed containers. The aim is to provide correct information to consumers and, secondly, to facilitate safe and unified control of this product in the different Member States.

3.6 Designations and definitions of olive oils and olive pomace oils

The Community intends to approximate its description and definitions for olive oils and olive pomace oils to those recommended by the International Olive oil Council. The descriptions and definitions of olive oils and olive pomace oils referred to in article 35 of Council Regulation no. 136/66/EEC were last amended by Council Regulation (EEC) no. 356/92 of 12 February 1992.

3.7 Trade within the Community

As a general rule, the principle of free circulation within the community is applied with two important exceptions:

- Monetary Compensatory Amounts (MCA): Although provision is made for the MCA under Council Regulation (EEC) no.136/66, in practice they are not being applied in the olive oil sector due to its high custom tariffs.
- Accession Compensatory Amounts (ACA): These are applied during the transition period after the accession of a new Member State in order to align the prices fixed in the new Member State with the common EC prices. The ACA are designed to correct price differences gradually. In spite of the provisions of the Acts of Accession of Spain and Portugal, the ACA, which were last fixed by Commission Regulation no. 3094/92 of 27 October 1992 have currently been removed for these two countries. In the case of Spain, they were removed by Council Regulation (EEC) no. 3815/92 of 28 December 1992, which became effective on 1 January 1993, and in that of Portugal, they were removed by Commission Regulation (EEC) no. 741/93 of 17 March 1993, which was effective as of 1 April 1993.

4. Community policies on other fats and oils and other liquid vegetable oils

Title III of the Basic Council Regulation (EEC) no.136/66 regulated the system to be applied to colza and rape seeds and to sunflower seeds and applicable to other oilseeds at the discretion of the EC Council.

Until 1992, two institutional prices were fixed annually by the Community for colza and rape seeds and for sunflower seeds: a target price and an intervention price. For soya beans a target price and a minimum price were fixed and for linseed only a target price was fixed.

Moreover, every year the Council established a guarantee threshold for colza, rape seed and sunflower seed.

The basic Regulation also introduced a system of aid, but this system was changed as a result of the judgment passed by the GATT «Soya panel». The change occured concomitantly with the adoption of a similar system for grains and protein crops and was covered essentially by Council Decision no. 93/355/EEC of 8 June 1993 and Council Regulation (EEC) no. 1765/92 of 30 June 1992. The reforms aimed to progressively adapt. In current purchase prices in the Community to world prices order to remedy the loss of income for farmers, a «compensatory payments» mechanism was devised per hectare cultivated.

The Blair House agreement (3 December 1992) between the European Economic Community and the United States of America which was later incorporated into the community regulations for oil crops allows for a Basic Community Surface of 5,128,000 ha for oil crops in general as from 1995-96. This surface is reduced by the percentage of lands removed for every crop year and which shall not be below 10%. This gives the Corrected Separate Basic Surface.

These Basic Surfaces have since been transferred nationally and the amount for each Member State was fixed according to the historic importance of their oil crops during the period 1989-91. If, in one trading year, the surface growing oil crops in the EC exceeds the Corrected Separate Basic Surface, the following penalties are applied:

- for every 1% in excess, aid is reduced by 1%.
- the percentage reduction in aid is also transferred to the following trade year.
- the penalties will only be applicable to States exceeding their respective basic surfaces.

With respect to trading systems, EC policy up to now on oilseeds and the resultant vegetable oils particularly can be summed up as follows.

- In the case of imports, the Common External Tariff (CET) is applied. The Council may also charge a compensatory monetary levy on the importation as such products when, owing to the quantities imported and the conditions ruling importation, or else as a result of bonuses or subsidies granted by one or several third countries, the resultant situation causes or risks causing serious damage to production of these products within the EC.
- In the case of exports, a refund is granted on oilseeds harvested in the Community that are exported to third countries. The amount of this refund is, at the most, equal to the difference between prices within the Community and world rates if the former are higher.

International trade

1. General regulations for trade with third countries

One of the basic principles of the EC is to give preference to Community products. In line with this principle, the former system of national customs tariffs was replaced by the Common Customs Tariff (CCT) with «ad valorem» duties which, in the agricultural sector, tend to be fairly protectionist. But the application of the CCT in this sector is more an exception than a rule and other mechanisms were set up for the EC trading system with respect to exports. These are as follows.

2. General measures

Basic Council Regulation EEC no.136/66 describes a general system for trade with third countries based on import levies and export refunds.

2.1 Imports

Import licences and provision of security: The Basic Council Regulation no. 136/66/EEC stipulates that any import into the Community of olive oil or of oil olives shall require an import licence. The issue of such licences shall be subject to the provision of a security guaranteeing the undertaking to import during the period of validity of the licence.

Import levies: Such levies are covered under articles 14-17 of Council Regulation no. 136/66/EEC, which was modified on this point by Council Regulation no. 1562/78 and no. 3994/87 and their implementing regulations. They are applicable to imports into the Community from third countries. The objective of such levies is to defend the community market because Community prices are generally higher than those on the world markets. They are collected at the place of entry and the amount charged depends on the difference between these two prices.

Levies are fixed by the Commission following different procedures, depending on the product in question. In the case of olive oil, two types of price are taken into account: the threshold or entry price and the CIF import price.

The levies vary depending on the product involved: the method followed in the olive oil sub-sector is to fix a levy for virgin olive oil with an acidity of 3 degrees expressed in oleic acid. This levy can be used to calculate the sum to be applied to refined oils and other products in the sub-sector.

In addition to the common law system described above, there is also a tendering procedure designed for when it is not possible to determine world market trends. No provision was made for this procedure when the Basic Regulation no. 136/66/EEC was initially drafted. However, its subsequent introduction proved necessary owing to the difficulties often encountered in calculating this levy. The general rules for fixing the olive oil import levy by tender are covered in Council Regulation no. 2715/78 of 23 November 1978.

2.2 Exports

Export licences and provision of security: According to the Basic Regulation no. 136/66/EEC, all exports of olive oil from the Community are subject to the presentation of an export licence. The issue of such licences shall be subject to the provision of a security guaranteeing the undertaking to export during the period of validity of the licence.

Export refunds: The provisions on refunds are covered under article 20 of the Basic Regulation no. 136/66/EEC, which usas last modified on this point by Council Regulation (EEC) no. 1562/78, for which the detailed rules of application were fixed by Council Regulation (EEC) no. 1650/86 of 26 May 1986. Refunds are applied when olive oil is exported to third countries if the price of olive oil in the Community is higher than world rates. The difference between both prices may be covered by a refund.

Refunds shall be determined taking into consideration the current situation and trends for olive oil prices and stocks within the Community market and on the world market for olive oil prices.

However, if the world market situation does not allow the most favourable prices to be determined, then the price on the world market of the main competing vegetable oils may be taken into account in addition to the difference between this price and that of olive oil over a representative period.

Export levies: In certain cases, Community regulations may establish levies on exports of those products which might create serious deficiencies in supplies within the Community as a result of massive exports to third countries when Community prices are lower than world prices. These levies may only be applied when the world market price is higher than the Community price. In the case of olive oil, these levies are referred to in Council Regulation no. 136/66/EEC and in the implementing Commission Regulation no. 120/89 of 19 January 1989.

Protective measures: The conditions for the application of protective measures in the olive oil sector are defined in Council Regulation (EEC) no. 2596/69 of 18 December 1969. The aim of such measures is to palliate, when necessary, serious market disturbances or to remove the threat of such disturbances. They are applicable for trade with third countries but may only be put into practice for certain sources, origins, destinations, qualities or presentations and for imports to certain regions of the Community or exports coming from these regions.

3. Special arrangements with non-Community countries

Being an important trading power, over the years the Community has built up a complex system of multilateral and bilateral trade relations.

It has developed specific links with non-Community countries by virtue of geographical proximity (agreements with the countries of EFTA, Eastern Europe and the Mediterranean basin), the existence of long-standing colonial links (the Lomé Convention) or similar levels of development (United States, Japan and other countries of the OECD).

3.1 Agreements with Mediterranean countries

Since the creation of the Community, and especially since the Paris Conference in 1972, the EC has reached a number of agreements with non-Community Mediterranean countries, including important olive-producing countries. These agreements are of two types:

- Association Agreements, based on article 238 of the Treaty of Rome. At present the EC has links through this type of agreement with Turkey, Malta and Cyprus.
- Cooperation Agreements, based on article 113. Agreements of this type have been reached with the rest of the non-Community countries within the Mediterranean basin, with the exception of Libya and Albania.

Agreements with Mediterranean IOOC-Member countries:

3.1.1 Cooperation Agreements with Morocco and Algeria

These agreements were signed on 25 and 26 April 1976, respectively, and entered into force on 1 July 1976. They have since been amended on several occasions.

With respect to olive oil, special procedures were designed to calculate the tariff reductions. However, in Annex B of the agreements it is stated that the Common Customs Tariff could be increased to include an additional sum, the amount of which would be fixed periodically by letter between the contracting parties.

A new agreement is expected to be negotiated to improve the import system between Morocco and the EC and Algeria and the EC.

3.1.2 Cooperation Agreement with Tunisia

The Cooperation Agreement between Tunisia and the EC was signed on 27 April 1976 and came into force on 1 July 1976, following which an additional Protocol was signed in 1987.

Special measures, applicable until 31 October 1995, have been fixed for the importation of olive oil from Tunisia. The most important one is the fixing of a special levy for a set quota per crop year.

A new Agreement is currently being negotiated with Tunisia. This is to be an Association Agreement which should improve the conditions in which Tunisian olive oil is exported to the Community.

3.1.3 Association Agreement with Turkey

An Association Agreement was reached with Turkey in 1963 providing for a first 5-year phase for restructuring for which financial aid was provided, and a second stage basically covering the adoption of measures to dismantle tariffs and liberalise trade.

After being broken off on political grounds, Community-Turkish relations were resumed in 1988. The gradual reduction in tariff duties provided for in the Agreement programme was thus resumed in 1988 and the date for the reciprocal liberalisation of agricultural trade was set for 1995.

With respect to olive oil exports, Turkey benefits from an abatement of the levy applicable to its olive oil exports. In addition, Annex IV of the EC-Turkey Association Council Decision no.1/77 of 17 May 1977 lists the new import concessions for Turkish agricultural products.

3.1.4 Trade Agreement with Israel

Negotiations initiated in 1962 with the EC resulted in the conclusion of a non-preferential trade agreement in 1964. Soon afterwards, talks in 1968 led to a preferential agreement signed in 1970. Further negotiations held in 1973 ended in a new agreement in May 1975 which entered into force on 1 July 1976 and which, apart from its trade provisions, included several actions to be taken in the fields of production, economic infrastructure, trade promotion, fishing and industry as well as in science, technology and environmental protection. This agreement also included a list of agricultural products entitled to tariff abatement.

At present, the EC and Israel are negotiating a new agreement.

3.1.5 Agreements with Yugoslavia

The EC reached a trade agreement with the former Federal Socialist Republic of Yugoslavia on 26 June 1973 which entered into force on 1 September 1973 and in which both parties aimed to increase their trade links and promote economic cooperation as far as possible. On 2 April 1980, a Cooperation Agreement was reached which aimed to promote technical cooperation more than trade links.

3.1.6 Association Agreement with Cyprus

The Association Agreement between the EC and Cyprus was signed on 19 December 1972 and entered into force on 1 June 1973. The first stage ended on 30 June 1977 and an agricultural protocol was signed on 1 May 1978 covering most Cypriot exports.

3.1.7 Interim Cooperation Agreements with Egypt

This Agreement was signed on 18 January 1977. The agreement provides for a system of privileged access to the Community market covering most agricultural exports.

3.2 EC Agreement with the European Free Trade Association (EFTA)

The EFTA Member countries (Austria, Finland, Iceland, Liechtenstein, Norway, Sweden and Switzerland) represent the main market for Community exports with over one quarter of EC foreign sales. The Community in turn purchases over half of the EFTA exports.

The first agreements reached by the EC with these countries were signed in December 1972 and entered into force in January 1973. In the Luxembourg declaration in 1984 these organisations expressed their determination to intensify cooperation with a view to creating a European Economic Area (EEA). Negotiations for the creation of the EEA began in 1990 and concluded with the signing of an agreement between the EC and the Member countries of the EFTA on 2 May 1992. The EEA agreement establishes the common objectives and basic principles for putting into effect the free circulation of goods, workers, services and capital, and additional policies on social matters, training, research, the environment, etc. aim to reduce social and regional differences between the parties to the agreement.

3.3 Current situation of the negotiations on the General Agreement on Tariffs and Trade (GATT)

The objective of the General Agreement on Tariffs and Trade (GATT) is to achieve the greatest possible liberalisation of world trade. The basic instruments used to try to put this into practice have been the successive multilateral trade talks called Rounds, the last of which, the Uruguay Round, started in 1986 and ended in December 1993. It was in this Round that, for the first time, agriculture and services were included in the GATT schedule of negotiations.

The liberalising intent behind the EC led it to participate actively in the Uruguay Round of the GATT as in previous Rounds. Since the Treaty of Rome grants the Community authority in matters relating to foreign trade, the Commission acted as sole negotiator and spokesperson on behalf of its Members.

Considering that the Uruguay Round negotiations have only just finished, it is impossible to know what the effects will be. However, mention should be made of the most important measures which may affect olive-growing.

The agreement adopted on agriculture comprises four elements: a basic agreement together with an agreement on methods to establish specific and binding undertakings in the framework of a programme for reform, a decision on the application of health and plant health measures and a declaration on measures to aid developing countries which are net importers of food products.

The main measures can be analysed as follows.

In relation to market access, it was decided to apply tariffs whereby all non-tariff protection measures at frontiers are replaced by tariffs affording the same degree of protection. The resulting tariffs should be reduced by 36% over a period of 6 years in the case of developed countries and by 24% over 10 years for developing countries. Less advanced countries are not required to reduce their tariffs.

With respect to internal support measures, these are to be divided into two categories - the types of aid that tend to distort trade such as production and consumption aid («amber policies»), and policies that have minimum effects on trade such as aid for research, disease prevention, infrastructure and environmental protection («green policies»). It was only agreed to reduce the «amber policies». This may affect the production and consumption aid granted by the EC because in general such aid is calculated according to the quantity of oil produced and the amount consumed.

Thirdly, an undertaking was reached to reduce subsidised exports. Reductions will take place over a 6-year period in the case of developed countries and will be applied to budgetary payments and to the amount of subsidised exports. An undertaking was also reached to not introduce or reintroduce subsidies for the export of products in respect of which export subsidies had not been granted during the period 1986-90. Conditions are less strict for developing countries, whereas less advanced countries shall be exempt from any such reduction.

The effects on the olive oil sector of this provision for subsidised exports will be a drop in the quantities exported with 20% subsidies and a drop in the overall volume of export aid for olive oil of 36%. By the end of 2000, the quantity of subsidised exports from the EC will not be allowed to exceed 116,900 t and the funds used may not exceed 55,000,000 ECUs.

Finally, it is possible for the contracting parties to apply special clauses so that, under certain conditions, a country may restrict imports.

The fact that these agreements were reached means that it should be possible to significantly increase world trade in olive oil because countries are obliged to reduce obstacles to imports.

TUNISIA

General Information

Tunisia is the largest olive oil producer in the world after the EC. In 1986 olives grew on 1,400,000 Has., with a total of over 55 million olive trees of which 11 million were not yet producing. Over the last three crop years there has been a surprising increase in production with the 1991/92 figure exceeding 200,000 tonnes.

Great changes are being introduced into Tunisian olive-growing policy which mean that it must be studied in two phases: the first before and the second after the Decree 93-2328 dated 27 October 1993 organising the 1993/94 crop year.

- First phase: Trade in olive oil and olive pomace oil in Tunisia was subject to a government monopoly. The body set up by order in Council no. 62-64 of 30 August 1962 to manage this monopoly is the National Oil Office (ONH), a public organisation of an industrial and commercial nature, which acts as a financially-independent public authority.

  In November 1967 institutional reforms were introduced, one of which was the creation of the Central Union of Oil Cooperatives (UCCO) which was made responsible for performing some of the duties of the

ONH. However, the role of the UCCO was not confined to reorganising the oil market but also involved promoting and diversifying vegetable oils.

The National Oil Office was then reorganised by order in Council no. 70-13 of 16 October 1970, and was entrusted once again with full management of the monopoly. This order was subsequently amended in 1971 and 1973, and lastly by Decree no. 80.409 of 15 April 1980.

Other very important organisations were set up in the olive oil sector, notably the Olive Institute which was created in 1982 by Decree no. 82-1454 of 19 November 1982 with the brief of carrying out research, studies, experimentation, information and intervention in order to develop and promote agronomic, technological and economic aspects of the olive oil sector. Another major organisation is the National Institute for Nutrition and Food Technology which mainly carries out research and control in the fields of nutrition and food.

- Second phase: Changes in Tunisian olive oil policy have been taking place gradually. In 1986 a programme of economic reform and structural adjustments began to be applied throughout the country with the support of the World Bank and the GATT. The objectives of this plan included the liberalisation of foreign trade and the dismantling of most of the State monopolies.

The government monopoly for the commercialisation of olive oil and olive pomace oil was abolished by means of Decree No.93-2328 dated 27 October governing the 1993/94 crop year, and Law No.94-37 of 24 February 1994 (published in the Official Bulletin of the Tunisian Republic on 1 March 1994).

The National Oil Office, therefore, no longer has a monopoly over trade in olive oils and olive pomace oils. Peddling in olive oils is now permitted throughout the Republic and olive oils may be purchased in unlimited quantities either directly from the producers or from ONH stocks.

However, the role of the ONH continues to be of great importance. Producers can pass the olive oil produced in their mills to the ONH, whether the oil comes from olives purchased by them or belonging to them or if provided by their customers. Such mills are considered ‘collection centres’ and as such must follow all the instructions given by the ONH.

Measures to improve production

Tunisia is making great efforts to restructure and modernise oil production and to improve oil quality, in addition to increasing considerably the surface area of olive orchards. These efforts have been seen over the years in a number of programmes which aim to improve both olive production and the olive industry as a whole.

Programmes to improve olive production: These mainly involve the creation of intensive irrigated orchards for table olive varieties, breeding nurseries, plant health protection measures, fertilisation, regeneration of orchards, grafting and pruning methods and the reconversion and improvement of productivity of oil olives.

Programmes to modernise the olive industry: The five-year plans generally include measures to update the olive industry. The VII and VIII Development Plans, for the periods 1987-91 and 1992-96 respectively, also included in their objectives the quantitative and qualitative improvement of olive oil production, the modernisation of existing oil mills and refineries, the creation of units in under-equipped areas as well as the utilisation of by-products.

Projects: Two other projects which had a great influence on the sector were the FAO-SIDA TUN 1 and the IRQ 501 projects.

The methods of intervention used by official organisations are basically loans, subsidies, training, research, studies and information campaigns.

Domestic trade and consumption

Before the monopoly was abolished, the ONH was responsible for trade on the domestic market of olive oil, olive pomace oil and other edible vegetable oils.

Until the enforcement of Decree No. 93-2328, consumption was restricted. No family could exceed the maximum quota of oil consumption. This quota could be withdrawn from the mills by producers or could be bought at the mills by non-producers. Now, as a result of the liberalisation of the olive sector, olive oils can be purchased with no quantity restriction.

International trade

Tunisian export policy is changing. Since 1986 a programme of economic reform and structural adjustment has been applied in Tunisia with the support of the World Bank and the GATT. Operators are now allowed to export olive oil as long as they are granted the appropriate authorisation by the authorities.

TURKEY

General information

In 1993 there were 877,700 Has of olive orchards with a total of 87,705 million olive trees, of which about 6 million were not yet productive. There are around 320,000 family-sized olive orchards of which 14% belong to three cooperatives: Taris (with 15,000 members mainly producing olive oil and, to a lesser extent, table olives); Güneydogu Birlik (with 1,250 members for olive oil); and Marmara Birlik (with 30,000 members, mainly producing black olives).

While the government is directly involved in designing olive oil policy, these cooperatives play an essential role because they are managed by government representatives and are responsible for purchasing operations, stocks and, in some cases, exports and imports.

Measures to improve production

In view of the importance of olive oil production in Turkey, efforts have been made, especially in traditional olive-growing areas, to plant new orchards and improve existing orchards by mechanising cultural care and introducing modern pruning techniques and other cultural care operations. A number of specific measures have been taken including the following:

- Experimental orchards are being set up in the different olive-growing areas to demonstrate to olive growers how yield can be increased by providing correct cultural care.
- Courses are being held in the main towns in the olive-growing areas to increase producers' know-how and demonstrate techniques for grafting, pruning and fertilisation.
- Information campaigns are being carried out to inform farmers of the findings of research and of technical matters of interest to them, with special care being taken to ensure that the information reaches farmers direct.
- Products are provided for pest control. Team work is encouraged for pest and disease control.
- Programmes to modernise the oil industry (67% of oil mills continue to use traditional systems).

Domestic trade and consumption

Over the last decade, Turkey has liberalised to a great extent its policy and trade practices in relation to olive oils and other edible vegetable oils. However, in view of the social and economic importance of the olive sector in this country, the State has had to adopt measures to protect producers and to compensate for the irregular bearing patterns, levelling out excessive price fluctuations. Olive oil was included in 1966 in a list of products receiving special support.

At the beginning of each crop year, the Ministry of Industry and Technology fixes a basic price for olive oil having 5 degrees of acidity. The main representative organisations within the olive sector are consulted and account is taken of production, stocks, costs and market prices. This price is ratified by the Higher Coordinating Committee for Economic Affairs.

Once the basic price has been determined, the above-mentioned unions of cooperatives are appointed by the government to carry out support purchases at this basic price. TARIS is by far the most important union of cooperatives. It buys in olive oil from its members at just above the intervention price and provides technical assistance and loans for pesticides and fertilisers to be paid back when the oil is sold. The olive oil bought in by TARIS in this way is stored and used as a buffer stock when necessary.

In the case of table olives, the Marmara Birlik Union fixes the purchase price for the best variety, Gemlik. This acts as a reference price for fixing the prices of other varieties.

Where olive oil is concerned, prices and eating habits are the prime factors that affect consumption. In order to boost consumption, the public authorities are striving to guarantee the authenticity of olive oil by implementing suitable regulations. Direct advertising is carried out by private sector companies which promote their own brands.

International trade

There are only occasional imports of olive oil. Surplus production is, however, often exported. Total production of other edible vegetable oils is not sufficient to meet internal demand and these are imported regularly. Exports are mainly of lampante oils because only very small quantities of edible virgin oil and refined oil are exported.

Since the Decree of 13 December 1990, no export subsidies have been granted.

The only measure designed to promote exports is the export tax refund. All taxes and duties paid from the olive orchard to exportation are refunded to exporters in line with legal provisions.

As with exports of many other products, olive oil exports are subject to quality control in compliance with Regulations for Edible Olive Oil and regulations covering the corresponding Methods of Inspection. These came into force in 1967.

MOROCCO

General information

In Morocco the olive is the most predominant fruit tree. In 1992/93 it was estimated that there were 39.5

million olive trees, of which 13% were not yet bearing. The total surface area of olive orchards is 395,000 hectares. Olives can be found in almost all the country although there are two main regions - Fez (centre) and Marrakesh (south), each of which grows 25% of the Moroccan olives.

Measures to improve production

At present, of the total production, one quarter is for table olives giving a trade volume of 50-60,000 tonnes. The remaining three quarters are for oil production.

State intervention aims to teach farmers to manage their assets better and to apply rational techniques to their orchards. A programme named «Improved olive production» was set up in 1969 and since then the state has made constant efforts in this fieldfocussingon:

- Research: pruning, mainly regeneration pruning; clonal selection; propagation by leafy stem cuttings; fertilisation, and pest and disease control.
- Extension services: delivery to farmers of selected plants; grafting and pruning; information on methods for pest and disease control, and training of experts in olive cultivation on provincial levels.
- Water supply and land use: This mostly involves the planting of olive orchards with a view to protecting and restoring soils.
- Oil processing: This activity can be divided into two sub-sectors according to the equipment used, whether traditional mills or relatively modern mills. The industrial sector covers both crushing and table olive processing whereas the traditional sector only carries out crushing. A programme to modernise the olive industry has recently been carried out (olive oil, olive pomace oil, the utilisation of by-products, etc.) and olive collecting centres have been set up.

The action carried out has mainly centred on maintenance work on 1,200,000 olive trees, free distribution of plants and the granting of loans to plant and maintain olive orchards via The National Bank for Agricultural Credit.

Domestic trade and consumption

Retail prices for olive oil are not fixed but prices of seed oils are completely controlled and regulated by the authorities. Compared with the other Mediterranean countries, consumption is very low and production is consumed largely in rural areas.

The efforts made in the oils sector have mostly been in connection with the modernisation of equipment with a view to improving the commercial quality of oils and making by-products more profitable.

International trade

Especially since 1963, Morocco has been regularly exporting olive oil although in small quantities. The main characteristic of Moroccan olive oil exports is that amounts fluctuate depending on crops and demand on the international market.

Morocco also exports table olives in quantities which vary from year to year (46,000 tonnes in 1993). These are basically bulk sales which are difficult to place on the local market.

One of the measures taken with respect to exports made it obligatory to obtain an export licence for any exports of olive oil and olive pomace oil.

Morocco only rarely imports olive oil. On the other hand, imports of other edible vegetable oils are high, averaging out at 178,833 t per crop year. The oils imported are headed by soybean oil, followed by colza and sunflower oil.

ALGERIA

General information

In 1991, olive farms in Algeria occupied 195,527 hectares (19.5 million plants of which only 10% had not yet started bearing). There are two main growing areas: traditional olive orchards covering 165,861 ha, 85% of the national potential surface area, and modern olive orchards covering a surface area of 28,139 ha. Production is mostly for table olives.

Methods of government intervention have varied considerably over recent years and in the second half of the eighties until 1990 the sector underwent a liberalisation process. Until then, the Algerian National Office for Agricultural Products had the monopoly of the sector. Since 1990, however, many different state authorities have been involved in the promotion of olive growing in Algeria. These include:

- the Institute for Fruit and Vine Growing Techniques, which carries out applied research on fruit trees, including the olive, and provides advisory services.
- the Union of Plant Production Cooperatives, which organises plant production in collaboration with the above.
- the Wilaya Department for Agricultural Services, which coordinates and provides information on technical activities.
- pilot farms
- the three Regional Offices for Olive Products, which aim to promote olive cultivation and the utilisation

of olive products and by-products. They also deal with processing and trade in olive products.

Measures to improve production

The State carries out various activities with a view to improving production, processing and trade in olive oil and other edible oils. The following are the most important.

A programme to improve olive farms in the traditional sector currently in force lasts until the year 2000. It covers the planting of new orchards and the regeneration of old trees.

With respect to modern olive orchards, actions have centred on the reorganisation of farms. Since 1987/88, the large independently-managed properties have been gradually replaced by cooperatives and individual farms.

The provision of seasonal and equipment loans is another frequent method used to promote production.

Olive pomace is not widely utilised. There are only three drying centres and no mills extract olive pomace oil. The Central Regional Office for Olive Products is planning to set up a mill for olive pomace oil extraction with a capacity of 50,000 tonnes.

Finally, with respect to table olives, most activity is carried out by the Western Regional Office which has 9 units producing table olives, three oil mills and one packing unit. The plant for the production units was purchased during the period from 1969 to 1976. The rest of the equipment dates from before 1962.

Domestic trade and consumption

There have also been important changes in the field of domestic trade since 1990. Until then, olive oil prices at consumer level were set by ministerial order for the whole country. The Algerian National Office for Agricultural Products controlled domestic trade, imports and exports.

Since 1990 the system has been liberalised and selling prices are now free. The public distribution offices (EDIPAL, EDG, ASWAK) continue to be involved in trade but only to a limited extent at between 10% and 15%. The rest of the production is sold freely outside the state structures by private dealers (both wholesale and retail).

Algeria has the lowest per capita consumption of fats and oils of all the Mediterranean countries. In the Central and Eastern regions, olive oil is traditionally the basic foodstuff whereas in the Southern and Western regions it has only lately begun to win favour in households as a customary part of their diet.

International trade

The importation of olive oil into Algeria is prohibited although approximately 319,167 tonnes of other edible vegetable oils are imported every crop year, mainly soya, colza and sunflower oils.

The Decree of 6 May 1964 made it possible to export olive oil on the condition that it complied with the terms of the Decree and was not blended with other fats and oils or any other type of product.

However, an interministerial order passed in 1977 then banned all exports of staple commodities, including olive oil, although 600 t of olive oil were exported in 1987/88.

ISRAEL

General information

There are two types of olive orchard in Israel - firstly, the traditional orchards in the Upper and Lower Galilee areas and, secondly, the new intensive, irrigated areas in the Jordan Valley area.

Measures to improve production

The main problems of the olive industry in Israel over recent years are the lack of labour, irregular bearing, limited choice of cultivars, many old orchards with low productivity and poor plant health.

Extensive research has been carried out to resolve these problems focussing on the following aspects.

1. Mechanisation of olive harvesting. Studies on mechanisation were begun in 1953 and have centred mainly on abscission products.
2. In the area of bioclimatology, studies have been carried out on the different factors affecting flowering and fruiting (irradiation, light intensity and temperature in the different geographic locations and on the four cardinal points of the tree) as well as on plant metabolism and alternate bearing.
3. The influence of water. Most of the table olive orchards in Israel are located on irrigated land and studies have been carried out on the different methods of irrigation, water dosage and fertirrigation.
4. Plant stock and propagation. Several trials have been set up on the acclimatisation of oil olive and table olive crops in arid zones and irrigated areas. Studies are also being carried out on cultural care techniques to shorten the period before trees reach maturity and on clonal selection and genetic improvement.

Israel has also been involved in the development and study of around 80,000 hectares of olive orchards on the West Bank, most of which produce oil olives.

International trade

Average figures for the last six crop years (1986/87-1991/92) show that Israel imports approximately 400 tonnes annually of olive oil and exports around 330 tonnes. The figures for other vegetable oils are larger with annual imports of around 86,400 tonnes of seed oils, mostly colza, soya bean, sunflower and corn oil.

YUGOSLAVIA

General information

Over the 1990/91 crop year, Yugoslavia had 2,836 hectares of olive orchards with a total olive production of 407,338 tonnes, of which 12,000 were processed as table olives and 395,338 tonnes as olive oil.

Measures to promote production

Measures are being taken to improve plant material, table olive production and olive oil production. In 1994 emphasis was placed on the creation of more modern olive orchards with 50 hectares being planted. The plan is to increase this figure progressively up to 200 hectares for the year 2000.

The Bar Institute for Subtropical Crops, set up in 1937, is the organisation in charge of all scientific and professional aspects related to olive cultivation.

With respect to improvements in the olive oil processing industry, attempts are being made to modernise production and continuous oil processing equipment has been purchased.

Work is also being carried out on improving technology for table olive processing and for oil and table olive packaging as well as increasing trade.

With a view to organising this work professionally, Yugoslavia has set up an Oil Association (YU Oils) with its headquarters in Brussels.

New situation

The changes that have recently taken place in the Federation make it impossible to provide further statistics or information on national policies in the olive sector.

CYPRUS

General information

In 1990 the island of Cyprus devoted a total of 7,250 hectares to olive orchards with 1,657 million olive trees, of which 1,510 were productive. The largest orchards are in the north. Average olive oil production from the 1986/87 crop year to 1991/92 was 1,750 tonnes with consumption standing at around 2,250 tonnes.

Measures to improve production

The objective of the national policy is to improve and increase production with a view to increasing the income of growers and improving their standard of living and the following measures have been taken by the government of Cyprus.

- In 1965 the Ministry of Agriculture began to apply a project to promote the planting of olive trees. Since then, nurseries have been set up in several regions to produce olive plants and sell them to farmers at partially subsidised prices.
- The Ministry of Agriculture has also made efforts to improve existing trees. The Institute for Agricultural Research is the organisation responsible for experimentation in these fields.
- The advisory departments of the Ministry of Agriculture carry out regular courses and demonstrations for farmers in the olive-growing regions.
- Olive growers are eligible for special terms for financing and loans.

Domestic trade and consumption

In spite of the obvious fluctuation in costs, until late 1967 there was no type of governmental support to guarantee producer income. However, since 1968 and with law 24/68 on trade in olive oil, specific measures have been taken to support olive production. At present, the government guarantees a minimum purchase price.

The Ministry of Industry and Commerce and the Olive Products Marketing Board are the official intervention bodies operating in the sector.

The Olive Products Marketing Board is the official organisation responsible for creating the most suitable conditions to motivate olive growers to improve the quality and quantity of their crops.

With respect to trade, the Cypriot Government has implemented the Olive Oil Law (Law no. 23/63 which was last modified by Law 59/93) which regulates the conditions for the purchase and sale of this product.

International trade

Since production is not sufficient to meet domestic requirements, about 300 tonnes of olive oil are imported annually. These imports are regulated in Cyprus by law 60/68 for trade in olive products. The Cyprus Olive Products Marketing Board is the only authority governing imports and exports, except for special authorisations given by the Board to private dealings.

Cyprus also imports almost 25,800 t of other vegetable oils to cover its requirements in fats and oils.

EGYPT

General information

In 1992 Egypt had 7.2 million olive trees growing on a surface area of 25,200 hectares. Practically all the olives produced were consumed as table olives. Olive oil production only just exceeded 750 tonnes.

Measures to improve production

Certain general measures of governmental intervention have been taken, especially by the Ministry of Health through its Department for Trade Regulation (Imports and Exports).

New orchards have been planted in recent years as a result of the activity of the General Organisation for the Development of the Desert.

Oil processing generally uses traditional equipment although recently there is a trend toward the installation of modern oil mills.

International trade

Since national production of olive oil is insuffcent, about 500 tonnes have to be imported annually to satisfy domestic demand for olive oil which is estimated at 1,500 t. However, to cover its home requirements in fluid edible vegetable oils, Egypt has to import seed oils. On average, it imports 93,000 t of cottonseed oil and 273,000 t of sunflower oil annually.

OTHER PRODUCER COUNTRIES

SYRIA

General information

This country has 405,000 hectares of olive orchards with 46.5 million trees, of which only 29 million are productive. Of the average of 350,000 tonnes of olives collected annually, 280,000 tonnes are crushed, giving 70,000 tonnes of olive oil. The remaining 70,000 tonnes are processed as table olives, most of which are locally consumed.

Measures to improve production

Olive cultivation receives official attention and support and the government provides the necessary means and equipment and adopts measures for the improvement of the sector such as loans for the creation of new orchards or the regeneration of existing orchards. The Ministry of Agriculture and Agrarian Reform carries out various activities including:

- the creation of nurseries for mist propagation to meet the increasing demand for plant material;
- the importation of machinery for cultural care operations;
- plant health protection including collective pest control treatments by spraying from the air;
- projects to set up irrigated orchards in the north.

Moreover, the Oil Office was created to act as a specialist centre for research and extension services amongst olive growers to teach them the latest techniques and providethem with up-to-date information.

Since most of the oil mills are old-fashioned, there is much wastage and the oils obtained are of poor quality. The government is therefore making attempts to modernise mills and to improve olive crushing potential, which is clearly insufficient, by introducing up-to-date mills equipped with super-presses or even more modern equipment.

Domestic trade and consumption

Domestic trade in olive oil, olive pomace oils and other liquid edible vegetable oils is carried out between producers and consumers via dealers and the appropriate state authorities.

International trade

International trade is governed by the Ministry of Agriculture and Agrarian Reform and the Ministry for the Supply of Food Products. State intervention is through the Regional Departments for the supply of food products.

Imports of edible vegetable oils apart from olive oil are currently authorised and average imports of these oils amounted to 19,333 tonnes for the five-year period from 1986/87 to 1991/92.

A Cooperation Agreement was signed between Syria and the EC on 18 January 1977 which gave access to the community market for most Syrian agricultural products under privileged tariff conditions.

ARGENTINA

General information

Argentina produces on average about 9,200 tonnes of olive oil (average for the 1987/88 to 1992/93 crop years). This quantity is small when compared with the production of other vegetable oils, which reached an average of 3,191,000 tonnes over the same period.

Measures to improve production

The aims of the Argentinian policy for production are:

- to reach such a level of production as to be able to meet domestic demand and export surplus production, thus benefiting the national economy;

- to stimulate production by means of minimum prices for seeds thus guaranteeing a fair income for producers, and actions to improve existing varieties or to create new varieties and promote mechanisation of cultural care;
- to facilitate medium-term loans at interest rates 5-8% below market rates.

The intervention organisations are the National Grain Board which acts on the market for seed crops and sometimes acts as sole purchaser and the National Institute for Agricultural Technology (INTA) which carries out its functions through experimental stations and extension offices.

International trade

Olive oil consumption in this coutry is lower than production which stands at around 4,100 tonnes and the rest is therefore exported. Duties, taxes and refunds are generally fixed according to the quality of the oils in question and the content of the packs. They also vary depending on whether the oil is for import or for export.

The Treaty for the Common Market of the South (MERCOSUR) was signed in March 1991 by Argentina, Brazil, Paraguay and Uruguay. Its objectives included the gradual abolition of all tariff obstacles between the Member States by 31 December 1995 and the coordination of national policies for trade, industry, agriculture and foreign currency, amongst others, for 31 December 1994.

JORDAN

General information

In 1990 Jordan had olive orchards on 54,742 hectares with 5.4 million trees, of which 26% were not yet productive. Average production per crop year during the period between 1986/87 and 1991/92 was approximately 8,000 tonnes.

Measures to promote production

The government is particularly interested in extending the surface area of olive orchards and is therefore making great efforts to provide sufficient new plants. The propagation system used is grafting onto rootstocks from nurseries as well as cuttings under mist.

International trade

Jordan has to import about 3,000 tonnes of olive oil per year, in addition to about 30,000 tonnes of various other edible vegetable oils.

A Cooperation Agreement was signed between Jordan and the EC on 18 January 1977 and established privileged access to the EC for a large number of Jordanian agricultural products.

LIBYA

General information

Libya is a small producer of olive oil. The average for the 1987/88 to 1992/93 crop years was 6,200 tonnes per year. This is not sufficient to satisfy domestic demand which stands at around 36,750 tonnes per year.

Measures to improve production

Measures are planned to promote oil production include the granting of loans for building and fitting out new oil mills which are then exempted from taxes for five years.

There is also state intervention in this sector. The National Company for Food Products undertakes to buy up all surplus olive oil from producers.

Domestic trade and consumption

Domestic trade in olive oil, olive pomace oil and other liquid edible vegetable oils follows the normal distribution circuit, namely wholesalers, cooperatives and retailers. Prices are fixed at the different stages of trade and consumption.

In order to ensure that oils are of good quality, it is compulsory for them to undergo laboratory analysis. Stocks are collected by the National Company for Food Products and are stored in its collection centres.

International trade

Libya imports around 21,800 tonnes of olive oil per crop year (this is the average for the period from 1987/88 to 1992/93). The National Company for Food Products is responsible for authorising imports. Over the last few crop years, owing to the international situation, olive oil imports have dropped to very low levels.

LEBANON

General information

In Lebanon there are approximately 5.5 million olive trees, 75% of which are adult trees, the rest being less than 15 years old. Average olive oil production (1986/1987-1991/1992) is 5,700 tonnes per crop year.

Measures to improve production

Although the olive is the most widespread fruit tree in the country, interest in olive cultivation has decreased over recent years as a result of various factors, especially the lack of labour and the difficulty of mechanising cultural operations. The small size of the farms, absentee landlords, competition from seed oils, etc. all aggravate the situation and have helped to gradually reduce profitability.

With a view to resolving these problems, over recent years measures have been implemented to protect plant health and improve production, on both national and regional scales.

These measures include plant distribution by the Institute for Agronomic Research (IRA), improved yield from old orchards, greater mechanisation of cultural operations, pest control and technical extension services.

Domestic trade and consumption

Although olives have been growing in Lebanon since time immemorial, olive cultivation is currently in decline. In addition, government policy is practically non-existent. There are no guaranteed minimum prices nor is there any production aid. Prices are set by the law of supply and demand between producers, growers and dealers.

International trade

Lebanon does not produce sufficient olive oil and imports an average of approximately 2,000 tonnes annually to cover its needs for consumption which stand at around 7,000 tonnes.

At present, olive oil may be freely exported as long as the appropriate quality certificates have been obtained. No duties are applicable.

A Cooperation Agreement has existed between Lebanon and the EC since 3 March 1977. While awaiting its entry into force, an interim Agreement was signed in the same year by the two parties. Olive oil is one of the Lebanese products which may be exported under favourable conditions to the EC under the terms of this agreement.

OTHER LEGISLATION

National legislation on products is generally based on the international standards set by various organisations; for the regulation of food products, governments generally base their legislation on the Codex Alimentarius Standards.

THE CODEX ALIMENTARIUS

As its name indicates, the Codex Alimentarius is a set of food standards compiled by a joint commission of the United Nations Food and Agriculture Organisation and the World Health Organisation. The Codex Alimentarius Commission brings together over 140 governments and a large number of international, intergovernmental and non-governmental organisations.

Since its creation in 1962, the Codex Alimentarius Commission has published over 220 food standards and 35 codes for hygiene and technological practices; it has assessed over 500 food additives and contaminants, has fixed over 3,000 maximum limits for pesticide residue and has drawn up general Standards on food labelling and transport.

The Codex Alimentarius Standards are prepared by the Commission and presented to governments for acceptance; recently it has been agreed to simplify food standards in order to facilitate their acceptance by governments.

The Codex Alimentarius Standards therefore give those provisions that are considered essential. These are used by governments as measures of control to guarantee public health and to ensure food safety and consumer protection. Certain of the provisions aim to ensure fair trading practices and prevent fraud. The annexes to the Standards give internationally-accepted composition and quality criteria which are recommended for inclusion in sale or purchase contracts.

On the subject of olive oil and table olives, the Codex Alimentarius Commission in collaboration with the International Olive Oil Council has adopted two standards:

- The Codex Standard for olive oils and olive pomace oils, CODEX STAN 33-1991, currently under revision by the Codex Committee for Fats and Oils, will be adopted in its revised version in 1997;
- The Codex Standard for table olives, CODEX STAN 66-1991-Revision 1 1987.

Each of these two Standards fixes the minimum criteria for composition and quality that products covered by the Standard must fulfil before they can be traded internationally; each Standard fixes the rules concerning food additives, hygiene, packing, labelling and methods of analysis to be used for the control of product purity and quality.

We respect to methods of analysis, the Codex Alimentarius refers to the work of the Codex Committee on Methods of Analysis and Sampling which recommends the application of its own methods or methods drawn up and adopted by specialist organisations such as the International Union for Pure and Applied Chemistry Society, IUPAC, the International Standardisation Organisation, ISO, and the American Oil Chemist's Society, AOCS.

ISO

The International Standardisation Organisation (ISO) is a worldwide federation of national standardisation organisations that brings together about 90 members, one from each country.

The work of ISO covers all areas of standardisation, except for standards on electrical and electronic technology which are the responsibility of the International Electrotechnical Commission, the IEC. The ISO and the IEC form the specialist method for worldwide standardisation, the largest non-governmental voluntary industrial and technical system of collaboration in the world.

The results of the technical work of the ISO are published in the form of International Standards; the work of the ISO is carried out by 187 technical committees and 630 sub-committees which are managed by the technical secretariats in 34 countries. The central secretariat of the ISO in Geneva coordinates the activities, ensures that the voting and approval procedures are properly applied and publishes the international Standards.

About 450 international organisations liaise with the ISO technical committees, including most of the specialist United Nations agencies.

The ISO coordinates the exchange of information on international and national standards, technical regulations and other documents of a regulatory type through an information network named ISONET which links the ISO information centre in Geneva with the national information centres in about 60 countries.

The links between the ISO and the International Olive Oil Council basically revolve around the work carried out by the sub-committees for agricultural and food technology on «Animal and vegetable fats» and «Sensory analysis» in relation to methods of analysis and their application to olive oils, olive pomace oils and table olives. Work is also been carried out between the ISO and the IOOC on olive oil extraction equipment, testing methods and vocabulary for oil processing.

IUPAC

The Commission for Fats and Oils that was set up with a view to unifying analytical techniques for the fats and oils industry and trade has worked under several names over the 90 years of its existence. In the area of the Division for Applied Chemistry of the International Union for Pure and Applied Chemistry (IUPAC) the Commission for Fats and Oils brings together chemists from about 30 countries to examine and finalise methods of analysis for application to fats and oils, to study analytical techniques and determire their reproducibility and repeatability by means of collaborative tests and to publish the texts as international IUPAC methods. The methods are applicable to oil seeds and fruits, oils and fats, glycerines and alkaline soaps.

The Codex Alimentarius Standards and those of the International Olive Oil Council refer to the methods of analysis published by the IUPAC and to those adopted by the ISO. For the same determination, the recommendation may be made to use either the IUPAC method or the ISO method, the two methods being similar or identical.

AOCS

Since its creation, the American Oil Chemists' Society (AOCS) has been in charge of drawing up methods of analysis for fats and oils and their derivatives, publishing them and circulating any information on fats and oils through journals, congresses, seminars and international activities.

The methods published by the AOCS are generally unified with those published by the IUPAC and the ISO.

The standardisation of products and the standardisation of methods of analysis and sampling are important in order for producers and dealers to use the same references.

WIPO

The World Intellectual Property Organisation (WIPO) for which the abbreviation in French and Spanish is OMPI, is an intergovernmental organisation established by the «Agreement to set up the World Intellectual Property Organisation» that was signed in Stockholm on 14 July 1967 and came into force in 1970. The WIPO acquired the status of specialist agency for the United Nations in 1974.

The role of the WIPO is to promote the protection of intellectual property worldwide through cooperation with States and to administer the various «Unions», each of which is based on a multilateral treaty, which work on the legal and administrative aspects of intellectual property. The first two «Unions» (L'UNION DE PARIS for the protection of industrial property, and L'UNION DE BERNE for the protection of literary and artistic works) go back to 1883 and 1886 respectively. The OMPI currently administers over 15 treaties or Unions.

Intellectual property covers two main areas: industrial property which mainly deals with inventions, brand names, design and industrial and cinematographic models; and royalties mainly in connection with literary, musical, artistic, photographic and cinematographic works. A large part of the OMPI activities aim to assist developing countries.

Chapter 13

THE INTERNATIONAL AGREEMENT ON OLIVE OIL AND TABLE OLIVES AND THE INTERNATIONAL OILVE OIL COUNCIL

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THE INTERNATIONAL AGREEMENT ON OLIVE OIL AND TABLE OLIVES AND THE INTERNATIONAL OLIVE OIL COUNCIL

EXECUTIVE SECRETARIAT
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OIL COUNCIL

Towards the end of World War II and immediately afterwards, especially at the close of the 1947/48 Havana Conference, the hope was that it would be possible to set up a proper network of product agreements that would organise the various commodity markets in order to ensure good distribution, price stability and equality of access amongst consumer States. Although the United Nations and, more particularly, the United Nations Conference on Trade and Development (UNCTAD) put a great deal of effort into this area, very few agreements were concluded.

In the case of olive oil, international action was called for to regularise, modernise and promote the sector owing to the specific features of the market, the limited number of producer and consumer States, the irregularity of production and major price instability.

The first International Olive Oil Conference was convened in 1955. The outcome was the adoption of the first international agreement in 1956, which was followed by a protocol in 1958 and the renewal of a second agreement in 1963 complete with amendments. This agreement was extended and amended on four occasions and was then replaced by a third agreement, known as the «1979 Agreement», and subsequently by the fourth «1986» Agreement.

THE INTERNATIONAL AGREEMENT ON OLIVE OIL AND TABLE OLIVES AND THE INTERNATIONAL OLIVE OIL COUNCIL

The International Agreement on Olive Oil and Tables Olives, 1986, which was extended and amended by a Protocol concluded in Geneva on 10 March 1993, came into force definitively on 25 March 1994.

The Members that have signed this Agreement are, in alphabetical order:

Algeria, Cyprus, the European Community on behalf of its Member States, Egypt, Israel, Lebanon, Morocco, Tunisia, Turkey and Yugoslavia.

Various countries also hold observer status to attend Council sessions and Committee meetings, specifically Argentina, Australia, Brazil, Bulgaria, Canada, Chile, China, Colombia, Costa Rica, Cuba, the Dominican Republic, Ecuador, India, Irak, Iran, Japan, Jordan, Libya, Mexico, Norway, Pakistan, Panama, Peru, Poland, Rumania, the Russian Federation, Saudi Arabia, Slovakia, the Syrian Arab Republic, Thailand, the United States of America, Uruguay and Venezuela.

The International Olive Oil Council also has cooperative or working ties with a large number of governmental and non-governmental organisations and agencies.

The International Agreement on Olive Oil and Table Olives is of major interest because of the advances it has forged, over the years, in conventional international law. It is one of the few flexible agreements to have been concluded as part of the organisation of the world commodity markets. More precisely, it is the only multilateral agreement on fats and oils now in operation.

Above all, the Agreement aims to be flexible and to regularise the market without using interventionist methods, unlike other «control» agreements to use the terminology of the Havana Charter.

From the legal standpoint, the Agreement is very progressive because the methods it applies for decision-making, signatures, entry into force and duration, settlement of disputes and amendments are often original and almost always marked by a concern for legal realism that is designed to make the Agreement effective. It is often, in fact, taken as a reference point for the negotiation of other commodity agreements.

The International Olive Oil Council was set up to see to the actual implementation of the Agreement and to monitor its application. Each Party to the Agreement is a Member of the Council, which has legal personality. The Council exercises all the necessary powers and has to perform all the duties required to implement the provisions of the Agreement, or to ensure that they are performed.

In particular, it is responsible for promoting any action to bring about the harmonious development of the world olive economy in the areas of production, consumption and international trade, bearing in mind the way in which they are interrelated, using all the means within its power.

It is authorised to undertake or to arrange for the undertaking of studies or other work with a view to framing any recommendations and suggestions to attain the objectives of the Agreement.

The Council has an Executive Secretariat to discharge the duties issuing from the Agreement.

FEATURES OF THE OLIVE OIL MARKET

The international olive oil market has some fundamental features that determine, either directly or indirectly, how it is organised from the economic and legal viewpoints.

GEOGRAPHICALLY SPEAKING, THE MARKET FOR OLIVE OIL IS LIMITED

This limitation characterises not only international trade but also production and consumption.

One reason for such geographical limitations is that olive oil production accounts for no more than a small percentage of the vegetable oils produced throughout the world.

But the situation is different in the Mediterranean countries where olive oil represents a very high percentage of domestic production of fats and oils. Although the Mediterranean countries suffer from a large shortfall in edible oils, they do produce a fairly large quantity of olive oil which, seen in regional terms, is of strategic importance to them as a whole.

Another reason why the market is geographically limited is that olive oil is mainly consumed in the countries where it is produced and, to a much lesser extent, at least over recent years, in countries with inhabitants of Mediterranean extraction or with a non-Mediterranean health-conscious or quality-conscious population.

The trend of world consumption gives a good indication of the importance of domestic consumption in the producer countries which stands at about 93% of available supplies. It also points clearly to the growing demand from non-producer countries that are aware of the advantages olive oil offers for human health.

A further reason for the geographical limitations to the olive oil market is that little olive oil is traded internationally and any trade is concentrated within the Mediterranean countries. However, trading outside the Mediterranean is growing and currently accounts for 19% in money terms, and 6% in quantity terms, of world trade in the major liquid edible vegetable oils. Put differently, when rated by the earnings it generates, olive oil lies third after soya bean oil and just below sunflower oil, and drops to fourth place when rated in terms of the tonnage traded, after soya bean, sunflower and rapeseed.

The fact that production is concentrated in a small number of countries and that there are geographical boundaries to both consumption and trading are factors that made it considerably easier to conclude an international agreement to regularise the market. An agreement on other commodities, especially in the fats and oils sector, would require the participation of a larger number of signatory States.

OLIVE OIL IS EXPENSIVE

As a rule, olive oil costs much more than other fats and oils. This higher price, which is warranted by the quality of the product, can be put down to several reasons to do with the cost of production (olive orchard productivity is poor, olive fruit harvesting costs are high and yields are low in olive oil extraction plants), the selection of olives intended for crushing, specific features of the fruit itself, etc...

This characteristic shared by the olive tree and olive oil production could well push up the price of olive oil even further if major efforts are not made to modernise the sector, to carry out research and development and to provide training.

This is one of the fundamental objectives pursued under the Agreement and makes a significant contribution to regularising and modernising the sector.

OLIVE OIL MAY FACE COMPETITION FROM OTHER EDIBLE OILS AND FATS

Although olive oil consumers are attached to their product, various vegetable oils and fats can compete with olive oil and take its place in specific price and supply conditions.

The possibility of substituting fluid oils and other fats results in imports into the olive oil producing nations which vary in amount depending on the supplies of olive oil available. What in fact happens is that the high price of olive oil prompts the governments of countries that both produce and consume this product to import much cheaper substitute fats when their olive harvest is not sufficient or when there is a shortfall in world requirements because the world olive harvest has been poor. In the developing producer countries, moreover, what happens is that part of the olive oil produced is exported to improve the trade balance by drawing in foreign currency earnings. The place of the olive oil that is exported is often taken up by imports of cheaper liquid edible vegetable oils. The result is that consumers in some producer countries are prompted to use competing products offered at more attractive prices. But, in the long term, this policy could well cause a serious risk of under-consumption of olive oil in these countries and could give rise to surpluses on the world market.

The upshot is that, besides action to cut production costs and raise productivity, it is also important in such cases to take action to regularise and promote olive oil. This last activity has to be carried out not only in and by the producer countries themselves, but also on the leading world consumer markets that have a high purchasing power.

This is another fundamental objective pursued under the Agreement, namely helping to promote the market.

THE WORLD OLIVE OIL MARKET AND ITS SPECIFIC PROBLEMS

If one looks at olive oil transactions on the world market, it emerges that this product is particularly vulnerable to two sorts of anarchic trading practices: speculation and fraud.

Speculation has frequently had a major part to play in creating price instability. Used to frequent variations in the volume of international trading, exporters and importers move into the market to capitalise on such fluctuations which they consequently make much worse.

Speculation of this sort is usually fostered by the shortage of price information on trends and prospects for production and consumption since there is no exchange or forward market for olive oil as there is for other commodities.

Another key objective of the International Agreement is therefore to organise an information service and to arrange for its studies to be circulated as far afield as possible, thereby making a very important contribution to market intelligence and stabilisation.

The fact that olive oil is dearer than other vegetable oils can prompt fraudulent mixtures or blends with inferior grades, and even sometimes with denatured oils of other types, which are fraudulently sold on the marketplace as «olive oil».

Operations of this kind create marked instability in production and gain a reputation for bad quality, especially in countries without a tradition of olive oil consumption. Monitoring of oil quality, brands and designations of origin should make it possible to curb such fraudulent operations.

And this is yet another of the essential objectives of the Agreement which features precise, detailed provisions on quality control. One specific activity in this area which dates back to 1992 is the quality control agreements signed between the chief trade associations in both producer-exporter countries and in importer countries in order to monitor the quality of the olive oils sold on the North American and Australian markets. These same associations requested the International Olive Oil Council to ensure that the monitoring agreements were properly implemented.

Another factor that has to be borne in mind is that some Mediterranean and non-Mediterranean countries where the climatic and agricultural conditions are right for olive farming are implementing agricultural development schemes in which olive orchards figure significantly.

Admittedly, a large part of new production will be absorbed by the new import markets, the current shortfall and the foreseeable population growth. Nevertheless, it is still both advisable and necessary to raise consumption considerably and this can only be done by running persistent, major and effective promotion and information campaigns targeted at olive oil consumers and potential consumers alike.

Yet again, as said earlier, this is one of the fundamental objectives of the International Agreement.

TECHNIQUES TO REGULARISE THE MARKET

The two characteristic traits of the International Agreement on Olive Oil and Table Olives - its flexibility and lack of interventionist measures - do not mean that it is not equipped with tools to regularise the market.

DRAWING UP RULES FOR INTERNATIONAL TRADE IN OLIVE OIL

All the agreements concluded so far have aimed to rationalise and regularise the market by combating commercial fraud, not merely to ensure legal, honest practices, but also to achieve economic stability and to uphold product quality. To do so, each of the agreements has been designed to introduce regulations and standards for international trade and to check for compliance at international level.

ECONOMIC MEASURES AND MEASURES TO STABILISE THE MARKET

Several provisions written into the Agreement allow the International Olive Oil Council to coordinate the national policies implemented in the olive sector, to avoid fluctuations and to adjust supply and demand. These provisions are very liberal and highly observant of the economic sovereignty of the Council Members. On the economic plane, they assign the Council and the bodies that issue from it extensive, often original functions in collecting information on, and coordinating, national policies in the olive sector.

LONG-TERM MEASURES TO STANDARDISE THE MARKET

One of the objectives of the International Agreement is to implement or facilitate the application of measures to expand international trade and consumption of olive oil and table olives.

The general measures advocated by the Council are well worthwhile in that they take into consideration the now widely-accepted principles of economic growth and social development.

The concept of achieving continuous economic growth and raising living standards calls for the adoption of a long-term policy to adjust supply and demand. However, owing to the specific nature of the market, this cannot imply taking corrective measures to restrict production. Modernising inputs is one management aspect that falls within the basic objectives of the Agreement since it aims to lower cost prices gradually and to improve the quality of olive oil and olives.

Clearly, no major olive farming development and technical improvement programme aimed at lowering cost prices can be implemented unless it receives adequate financing. The International Olive Oil Council has only very limited resources which, although they were doubled under the 1993 Protocol, do not enable it to provide all the assistance its Members need, especially its developing Members.

As specified in the Agreement, the Council relies heavily on cooperation with other organisations, notably with the Common Fund for Commodities in the shape of the facilities it offers through its Second Account. One result of this cooperation is a project for the genetic improvement of the olive which was drawn up by the IOOC Members and is being implemented together with the Common Fund.

PROMOTIONAL MEASURES

With the schemes under way to modernise olive farming in the Mediterranean region, any policy to regularise the market has to aim at and encourage major growth in the consumption of olive products.

Promotion is one of the tools that make it possible to attain the objectives of the Agreement since it helps to expand consumption of olive oil and table olives and highlights their health-related properties.

The promotion carried out by the International Olive Oil Council, which is financed by its Promotion Fund as well as by voluntary financial contributions from its Members, notably the European Union, is centred on three areas of work:

- conducting scientific research into the biological value of olive oil and table olives with the aim of scientifically highlighting their intrinsic properties, later using the findings to heighten consumer product awareness and as a source of promotional material;
- carrying out public relations work and generic promotion to inform and educate consumers as well as to provide international product support by backing or acting as a catalyst for national campaigns, both private and public;
- lastly, using the IOOC international guarantee label which, while initially designed as an additional promotional device, provides importers and consumers with a product guarantee.

CONCLUDING REMARKS

The various agreements that have been concluded since 1956 have made a significant contribution to the organisation of the international olive oil and table olive market in two ways: by setting up a permanent body and by introducing the means to regularise business transactions, to coordinate national policies and to adjust supply and demand in the long term.

The distinctive characteristics of the sector call for measures which very frequently overstep the regional framework of the Council Members and require coordinated international action which is the only way of aspiring to produce and market a quality product.

Stabilising, expanding and improving the market constitute a crucial objective that has to be maintained.

Instituting a constructive debate between the Council Members on the problems facing the sector and identifying and developing joint strategies are the ways to consolidate and achieve the objectives of the International Agreement on Olive Oil and Table Olives in the areas of:

- international cooperation and concerted action;
- the modernisation of olive farming, olive oil production and table olive processing;
- the expansion of international trade in olive oil and table olives; and
- the standardisation of international trade in the same two products.

POLICY ON THE OLIVE ECONOMY

As explained earlier, the existence of the International Agreement on Olive Oil and Table Olives is justified by the need to protect and promote the olive and olive oil sector owing to the socio-economic importance it holds worldwide, particularly in the olive-growing regions. The olive is a crop that is fully integrated into the social and economic structure of the regions with a tradition of production and consumption. These areas are primarily located around the Mediterranean where the olive is not readily replaced by other crops from the point of view of production, marketing and consumption owing to its environmental and economic characteristics. Why this is so is that:

- where production is concerned, the olive is generally grown in arid, impoverished areas where there is little industrialisation and where very frequently no other crops can be grown. The fact that other agricultural crops cannot be introduced convert this fruit crop into an excellent tool for preventing the lands from being abandoned, for preventing desertification and for curbing the depopulation of the countryside;
- where marketing is concerned, the fact cannot be overlooked that the olive tree provides an income for over two million families and olive oil and table olive exports represent a major source of foreign currency earnings, particularly for the developing countries;
- where consumption is concerned, olive oil and olives are staple foodstuffs for the peoples living in the olive-growing regions.

However, the olive comes up against serious problems, the most important of which are the sharp fluctuations that occur in production from one year to the next which make it almost impossible to keep yearly supply at a constant volume. Additional problems are the reluctance to accept technical and technological progress or the difficulties in implementing such advances, with the ensuing consequences for the profitability of olive farming.

All these problems are at the root of the irregularity of market supply, both in terms of quantity and quality, which leads to variations in prices and export earnings and fluctuations in olive farmers' incomes. Then there is the further question of the competition on the marketplace from other, generally cheaper, liquid edible vegetable oils.

The International Agreement on Olive Oil and Table Olives therefore faces the major challenge of initiating, and then sustaining, work to modernise and increase the returns from olive farming and olive oil production in order to strike a balance between production and consumption and so ensure that the market is supplied regularly.

One of the objectives pursued is to secure the right quality-to-price ratio to allow olive oil and table olives to be competitive on the market. It is therefore important to lower the costs of production and to upgrade product quality if olive farmers are to be secured a fair income that allows them to enjoy an acceptable standard of living while obtaining substantial resources to plough back into their businesses.

The problems in the olive sector are not isolated cases: on the contrary, they are generally common to all the producer countries. It is not therefore a question of looking for partial solutions at national level but of using every possible means to stimulate coordinated development and trans-national cooperation by acting on an international level, not only in conjunction with the governments of the Member States but also with the different professional categories in the sector.

It is particularly important to coordinate policy on foreign trade. The crux of the matter is that, irrespective of the imbalances that occur between national production and consumption figures, imbalances are also recorded between supply and demand in world terms, owing to fluctuating harvests or other factors. This is why it is important to ensure international coordination of any action to improve access to markets and food security, to prevent or, if necessary, combat any unfair trading practices and, in the final analysis, to expand national and international trade in order to boost export earnings, especially for the developing producer countries, thus also helping them to speed up their economic growth and social development.

To make sure that these objectives go beyond a mere declaration of principles, the Agreement created a body, the International Olive Oil Council, which was to «to promote any activities conducive to the harmonious expansion of the world olive-products economy by every means and encouragement in its power in the field of production, consumption and international trade, having regard to the ways in which they are interrelated». Equipped with its Committees and Executive Secretariat, the Council has the proper structure it needs to carry out its duties as regards organising studies and providing a forum for discussion, collecting information and designing and implementing projects, all of which combine to make it an active, dynamic instrument for bringing about improvements in the sector.

Part Three of the Agreement specifies the duties of the Council in the economic and standardisation areas.

In the economic area, the Council has the following responsibilities:

- It has to collect data on a regular basis on the production, consumption and international trade in olive oils, olive-pomace oils and table olives as well as on fluid edible vegetable oils more generally. It then takes this information to compile the balances for these products and to ascertain the policies that Members are implementing in their home olive sector.
- Twice a year, at the autumn and spring sessions, it examines in detail the figures for olive oils and table olives, makes an overall estimate of supply and demand and analyses the situation on the marketplace.
- It makes recommendations to Members for encouraging international trade in olive products and proposes suitable measures to remedy any problems that might upset international trade with a view to ensuring the right balance between production and consumption.

In order to reinforce its activities in this area and publicise them, the Council also publishes:

- an annual report on the policies being applied by the different countries in the olive sector;
- regular articles of an economic type giving facts, figures and graphs on the situation of the international market for liquid edible vegetable oils in general and the olive oil sector in particular in its official journal, *Olivae*, and in its bi-monthly information sheet.

In the area of standardisation, the role assigned to the Council is an essential one. It aims to harmonise national legislation and to eliminate obstacles to trade on both national and international levels while ensuring strict control of product quality and authenticity.

Work on standardisation is required from the preliminary stages of production right up to the final consumer stage and involves especially:

- the adoption of designations and definitions of olive oils, olive pomace oils and table olives taking into account their physical, chemical and organoleptic characteristics and the introduction of regulations for the indication of source and appellation of origin. The Council Members undertake to take measures to ensure compliance with such rules and to prohibit and erradicate incorrect practices in international trade;
- the introduction, in close collaboration with the Joint FAO/WHO Programme of the Codex Alimentarius, of food standards for olive oils and olive pomace oils as well as for table olives;
- the drawing up of trade standards and the adoption of a specimen international contract with a view to facilitating relations between buyers and sellers, combating fraud and unfair competition and generally controlling the quality, packing and labelling of olive products;
- the institution of the Board for Conciliation and Arbitration for disputes arising in transactions in olive oil, olive pomace oil and table olives. Under the terms of the Rules of this Board, an attempt may be made to settle any disputes by amicable agreement. If unsuccessful, the parties involved can determine that the Council should arbitrate. By submitting their dispute to Council arbitration, the parties undertake to implement the sentence immediately and to waive their right to any possible appeal. The arbitral award is final and has to first be approved by the Arbitration Board as to its form;
- the international accreditation of national laboratories.

The adoption of harmonised food and trade standards that are regularly updated in the light of scientific and technical progress not only guarantees that the consumer receives quality products but also facilitates the fight against fraud and adulteration. If such activities are not curbed they can damage the product image and upset the delicate balance on the international market.

On the matter of the regulation of international trade, the Council keeps in close touch with the world markets for olive products and offers its Members and Observers a forum for reflection and discussion in which they can defend the interests of the olive sector and basically achieve the wider aims laid down in the Agreement. Decisions are generally taken by consensus between the Members during the sessions that are held at least twice a year.

In order to properly fulfil this function as a forum for discussion, reflection and conciliation, the Council has also set up an Advisory Committee for Olive Oil and Table Olives, which enables it to find out the opinion of the different trade and consumer organisations and to collaborate closely and constantly with them. The task of this Committee is to assist the Executive Secretariat in the preparation of the different matters to be dealt with by the Council. It also forms an ideal framework for all those involved in the sector to meet regularly, exchange points of view and strengthen their collaboration.

The Council is also a research body and as such undertakes or commissions, prepares and publishes any reports, studies and other documents it considers useful and necessary to pinpoint the problems and constraints in the sector and to draw up appropriate recommendations to be presented to the Members.

Any studies and reports on economic and/or commercial subjects should centre on finding the ways and means to ensure balance between production and consumption and long-term standardisation of the olive oil market and should aim to provide suitable solutions to any problems that might arise for the olive product market worldwide.

All these studies and reports should cover the largest possible number of countries or groups of countries and should take into account their general, social and economic conditons.

There is little the Council can do without effective international cooperation. There must be close collaboration at all levels with its Members and the non-member States involved in international trade in olive oil, olive pomace oil and table olives, and official or working links with the United Nations Organisation, the United Nations Conference on Trade and Development as well as the United Nations Food and Agriculture Organisation. In addition, the Council may consult or collaborate with other specialist bodies of the United Nations Organisation as well as with any appropriate intergovernmental, governmental or non-governmental organisations.

POLICY ON TECHNICAL COOPERATION

From the start, the International Agreement has been of assistance to the Member countries, particularly the developing countries, in solving problems within the sector and contributing significantly to the attainment of the aims outlined in the policy for modernising olive cultivation, olive oil processing and the table olive industry. Efforts have centred on:

Promotion of activities in research and development to establish techniques aiming to:

- modernise olive cultivation and the olive oil and table olive industry by means of appropriate scientific and technical programmes;
- improve the quality of olive oil and table olives;
- reduce the cost price of these products, especially that of olive oil in order to improve its position in the international market for vegetable oils;
- improve the situation of the olive industry in terms of its influence on the environment in order to correct any harmful effects it may have, in line with the recommendations of the United Nations Conference on the Environment.

Promotion of the transfer of technology and training within the olive sector.

Especially since the 1986 Agreement was signed, the IOOC has been the ideal structure for the development of efficient multilateral technical cooperation between all its Member countries with a view to finding joint solutions to their basic problems.

The main problem concerns productivity which is far from satisfactory and tends to be very low in the olive oil sector. On top of this, the high price of olive oil keeps consumption down and, since olive oil is generally produced in countries with a low level of purchasing power, potential consumers may be unable to afford it.

Improved productivity is basic to the future of olive cultivation in the Mediterranean and the situation is especially crucial in the countries of North Africa and the Near East. Non-existent or inappropriate fertilisation, the absence of plant health treatments or inefficient treatments, incorrect or excessive pruning, the use of olive varieties that do not have the necessary productive capacity and the phenomenon of alternate bearing are the main obstacles to productivity.

The essential characteristic of olive production is the irregularity and cyclical nature of harvests and market supply which give rise to fluctuations in the value of the crop, instability in prices and export earnings and considerable ups-and-downs in producers' income. Moreover, there is fierce competition from other lower-priced vegetable fats and oils. All of these factors cause imbalance in the olive oil market and the producer countries have set up protectionist policies for olive oil in order to counter these drawbacks. The aim is to fix olive oil prices at levels not much higher than those of seed oils. However, current trends are leading towards the gradual opening up of domestic and international trade, the gradual abolition of protectionist measures, the reduction of tariff barriers and the need for governments to ensure that domestic consumer demand for essential food products such as fats and oils is satisfied at low prices. All of this aggravates the situation of Mediterranean olive farming and the problems are especially great in developing countries that require modernisation of their productive, industrial and trade structures.

Production costs have always been high but in recent years they have shot up. Inputs, especially labour for harvesting and pruning, have increased in cost year by year and now account for 60 or even 70% of total production costs. This is obviously a key factor in the economy of olive orchards.

It is of no use to just wait for production costs to fall when and if prices for fertilisers, plant health products or labour fall. The only possible solution is to increase productivity, improving yield per hectare or per tree.

Concerning product quality, the problem is basically one of technological training and this can be solved to a great extent by a certain degree of intervention or programmes for extending know-how. Such actions are taking place in the developing countries in the southern and eastern areas of the Mediterranean basin in which the percentage of quality virgin oil produced is very limited.

The industrial structure of the olive oil industry in these countries has undergone very little in the way of modernisation and, although the natural conditions for producing quality oil are sometimes quite exceptional, a high proportion of the oils produced are defective and unsuitable for consumption unless refined. Insufficient technological training of the people working in the sector inevitably leads to low quality oil.

The restructuring and modernisation of the olive oil extraction industry also therefore requires updating the know-how of those in charge. The move from traditional oil mills to a continuous process can only be done if the traditional millers are given the right training.

Reducing production costs and improving product quality are therefore two basic requirements to make the sector viable at production level. Any actions in this area need to be integrated into a national policy that takes into account not only economic considerations but also certain other specific features of olive cultivation such as the social consequences for whole areas of production where the steps to be taken go beyond merely drawing up a market policy. The phenomena of depopulation of the countryside, erosion and desertification are not just empty words but a reality in many areas of the Mediterranean Basin in which olive cultivation is the mainstay of the economy.

This means that it is not possible to reduce olive oil production if we want to maintain equilibrium in the world olive oil trade balances; what we have to do is increase demand while taking into account the marginal olive-growing areas where a real social policy needs to be applied.

What is the experience of the International Olive Oil Council and what are the solutions it is trying to apply to resolve the problems in the sector?

It must be stressed that when the International Agreement on Olive Oil and Table Olives was being discussed in 1986, the problems of the equilibrium between supply and demand were already in the mind of most of the olive producer countries, especially the European Community. The concern at the time was to determine what measures would be covered by the Agreement to help solve the immediate and future problems in the olive oil sector.

In order to achieve the general aims of the Agreement concerning the modernisation of olive cultivation and oil processing, the technical cooperation activities in the Agreement were extended to cover:

– training of technicians and management with responsibilities in the sector (over the period 1987-93, a total of 870 technicians received direct training on new growing techniques, techniques for improving olive oil quality, training of supervisors for virgin olive oil tasting panels and technology for the production of table olives);
– the transfer of technology from the Member countries that are most advanced in olive oil techniques to developing Members;
– the development of research projects on matters of general interest for the Members;
– technical assistance to countries in drawing up and putting into effect their own national programmes for research and improvement, in line with local needs or priorities;
– logistic support to developing countries to assist them in setting up pilot olive oil processing plants, olive farming demonstration plots and laboratories to act as training and development centres;
– the establishment of efficient cooperative links between centres carrying out research and experimentation in the area of olive cultivation and olive oil processing with a view to encouraging the transfer of technology, facilitating the exchange of information and experience and speeding up the obtention of results by the correct allocation of tasks;
– the publication and circulation of technical documentation.

As a result of the actions carried out from 1987 to 1993 and in view of the interest shown by the Members in intensifying technical and technological activities to improve olive cultivation and processing, it was agreed, for the duration of the current Agreement, to raise the funds allocated to the IOOC for Technical Cooperation as from 1994.

In order to solve the main problems in the IOOC Member countries and especially those in the countries with the greatest needs, the International Olive Oil Council approved a Programme for Technical Cooperation for the period 1994-2000 determining the activities that would lead to the achievement of the aims of the Agreement as outlined in the policy for the modernisation of olive cultivation, olive oil processing and the table olive industry.

TABLE 1
GENERAL PROGRAMME FOR TECHNICAL COOPERATION 1994-2000

	Operations	**Target for improvement**
Programme 1	Research and development	
	– Genetic olive resources project	Productivity + quality
	– Research work on olive oil chemistry and sensory analysis	Quality
	– Preparation of a World Catalogue of Olive Varieties	Various
	– Project for genetic resources in olive cultivation	Productivity + quality
	– Crop health care	Productivity + quality
Programme 2	Training	
	– Organisation of intensive courses to specialise and update expertise (local and international)	Productivity + quality
	– Seminars and study meetings	
	– Grants for specialisation	
Programme 3	Technical support and assistance	
	– Creation of pilot demonstration centre for the improvement of olive oil quality and demonstration orchards	Quality + productivity
	– Logistic support for laboratories, institutes, etc.	Quality + productivity
	– On-site consultancy services	Various
Programme 4	Publication and circulation of technical documentation	Training + various

Programme 1. Research and development

This programme aims to reinforce research activities in the developing olive producer countries, the results of which are to be applied to both olive cultivation and olive oil production. The first of the research projects proposed is that for the genetic improvement of the olive which aims to obtain varieties suitable for each growing area with the right agronomic conditions for optimum productivity. The first results obtained after the three years of the project for genetic improvement will constitute the basis for subsequent work in each country.

The objective of this research project is to improve productivity in the olive orchards of the IOOC Member countries in the eastern and southern parts of the Mediterranean basin by obtaining new varieties to meet the requirements of more competitive modern olive cultivation.

With respect to work on research in the field of olive oil chemistry, the programme aims to set up reliable methods that will be internationally accepted and adapted to technological advances in the area of analysis. These modern methods will allow for good control of olive oil quality and the detection of fraudulent blends, the main objective being to preserve product quality and commercial integrity. In addition, within the framework of activities aimed at protecting quality, the programme covers work on ensuring the repeatability and reproducibility of the method for the organoleptic assessment of virgin olive oil as drawn up and adopted by the IOOC. Also, in line with the decisions taken in recent Sessions of the International Olive Oil Council, after the adoption of the revised method for the organoleptic assessment of virgin olive oil, methods will be drawn up for the sensory analysis of olive oils and olive pomace oil for consumption.

These physico-chemical methods are listed in the Trade Standard adopted and revised periodically by the IOOC for olive oils and olive pomace oils; the experts and panel supervisors from the institutes and laboratories in the Member countries that collaborate with the IOOC and that are in charge of proposing to the IOOC acceptable limits for olive oils and olive pomace oils for each of the criteria included in the Trade Standard, will be actively continuing their work within the framework of the programme.

These methods and the limits accepted by the Council for the different purity and quality criteria for olive oils and olive pomace oils will subsequently be included in the Codex Alimentarius Standard for olive oils and olive pomace oils.

In the area of table olive technology, new methods will be drawn up and circulated for improving the fermentation processes and final quality control; these control methods will then be included in both the IOOC Trade Standard for table olives and in the Codex Alimentarius Standard for this product.

It will also be necessary to finalise the work on the World Catalogue of Olive Varieties. The aim is that this should be a really useful tool for all those working in the olive sector, providing a complete overview of all the different varieties and information on their possible uses.

Olive oil quality continues to be a priority problem in the sector. Oils are still being produced with sensory characteristics that make them unfit for consumption unless first rectified. To remedy this, the IOOC has set up a Project for the Installation of Pilot Demonstration plants to improve olive oil quality in the IOOC Member countries in the eastern and southern parts of the Mediterranean basin. In these centres local producers can be trained in the latest technological advances in olive oil extraction.

Moreover, in order to make known and preserve genetic resources of the olive worldwide, the IOOC is to undertake a Project for the Conservation, Characterisation, Collection and Utilisation of the Genetic Resources in Olive. The decision to implement this project was based on the fact that the IOOC considers the genetic resources of the olive to be irreplaceable and that their conservation will help to protect biodiversity as stipulated in the Rio Convention on Biological Diversity.

The purpose of the project is to determine and preserve the genetic resources of the olive within the European Union (France, Italy, Greece, Portugal and Spain) and in other important olive-growing countries: Algeria, Morocco, Syria, Tunisia, Turkey and other countries in the Mediterranean Basin in which about 95% of the world's olive orchards are located.

A fund of knowledge of the genetic resources of the olive, as selected by farmers over the centuries, will be achieved by means of:

- the characterisation and assessment of the native varieties in the participating countries;
- the establishment of a data bank for the species; and
- the identification and inclusion in the collection of any native cultivars that are as yet unknown.

The preservation of the different cultivars in the countries considered will be done through selection from the various national germplasm banks, two of which will contain the majority of the genetic resources of this species. This will ensure survival and facilitate the study of this valuable material.

The project will make it possible to safeguard, characterise and assess the wide genetic variability of the olive. The results will constitute the starting-point for the following activities:

- sustainable cultivation in areas where olives are currently grown, most of which are located in marginal areas where no other crop can support the rural population;
- the extension of sustainable cultivation to areas where olives are not currently grown with the resulting benefits of protecting the land against erosion and desertification while diversifying production in these areas;
- programmes for genetic improvement of the species, currently only just under way;
- improved supply on the world market for olive oil for which, being a product of great value both for nutrition and for human health, demand has been increasing faster than production over recent years;
- improved olive oil quality, essential for sales to both traditional and new consumers.

Finally, attention is also to be given to the utilisation of the by-products of the olive since these comprise a source of additional benefit which could help to improve the profitability of olive farms. Research will therefore continue on the physico-chemical and biological properties of all the by-products of the olive.

Programme 2. Training

This programme includes continued efforts to make known modern techniques for olive cultivation and olive oil processing through the training of specialists who will then pass on the information to olive growers and oil producers.

This section of the Technical Cooperation Programme covers training on both local and international levels:

- Courses and seminars for local technical staff as well as for olive growers and experienced millers in their respective countries in order to improve and/or update their theoretical and practical know-how in their respective countries in the areas of olive cultivation and olive oil and table olive processing, at the request of the Member countries.
- The organisation of international courses, seminars and symposia so that technicians in the sector can obtain complementary training in the areas covered by technical cooperation.
- In view of the diversification of the olive oil sector in the areas of production and industrialisation, which requires very varied and highly-specialised skills, it

is proposed that grants should be awarded to encourage specialisation at post-graduate level in engineering or chemistry. Such grants could be for master's degrees, doctorates or for additional training for engineers from the IOOC Member countries, in institutes or centres specialised in olive growing and olive oil and table olive processing in Spain (Instituto de la Grasa y sus Derivados in Seville, CIDA in Cordoba), France (Ecole Supérieure Agronomique de Montpellier), Italy (Istituto di Ricerca sulla Olivicoltura di Perugia, Istituto Sperimentale per la Elaiotecnica di Pescara), etc.

- The Council will also adopt the necessary measures to organise study trips and technical visits for the training of technicians and professionals in the olive sector and will promote the creation of associations and collaboration between study and research centres, laboratories and other technical and professional institutions. The aim is to encourage the exchange of information, experience and findings.

Over the next six years (1994-2000), the training programme will have helped to improve the know-how of management and technical staff in the following subject areas:

- Cultivation techniques (pruning, irrigation, etc.)
- Plant health treatments
- Mechanised harvesting
- Improved oil quality
- Training of tasting panel supervisors
- Quality control. Chemical analysis. Training in the application of new methods.
- Table olive technology.

By organising international seminars and intensive courses, the Programme aims over six years to provide direct training for approximately 1,000 professionals. Courses will also be held within each Member country.

Programme 3. Technical support and assistance

This programme aims to provide technical and technological assistance to the Member countries for the setting up of national research and improvement programmes to meet their own local needs or priorities. Although the programme involves a number of activities of common interest, certain agricultural or local technological problems require different treatment, especially in connection with the following:

- Olive pests and diseases
- Fertilisation
- Pruning
- Irrigation: rational use of water in olive cultivation
- Olive oil processing
- Table olive technology

Logistic support is also to be given to developing countries to facilitate the creation of pilot centres, demonstration olive farms, laboratories, etc. which will serve as teaching and development centres.

This new line of action designed mainly for traditional olive farms in the Mediterranean basin will have a direct effect on productivity and olive oil quality and in general on all the factors and means of production and trade throughout the region.

Programme 4.

Publication and circulation of technical documentation

The aim of this programme is to reinforce international cooperation between centres carrying out research and experimentation on the olive in order to promote technology transfer, speed up research and facilitate the exchange of information, experience and know-how.

During the period of the technical cooperation programme, such collaboration between institutions will be stimulated and hopefully will continue in the future.

The inclusion in the Technical Cooperation Programme 1994-2000 of the publication and circulation of technical documents should achieve a triple aim:

- The creation of a Centre for Technical Documentation which should meet the information requirements of the various public and private organisations within the IOOC Member countries.
- Annual publication of the results of various research works (theses and reports on olive growing and olive oil and table olive processing).
- Publication of practical manuals on the subjects covered by technical cooperation, technical reports and other technical documents of interest (drawn up during courses, seminars, symposia, meetings, etc.)

As a result of the above mechanisms, it is now possible to act through the cooperation activities already under way in the olive-growing countries. In other words, there are now prospects for setting up large-scale programmes leading to increased productivity on olive orchards and in the olive oil industry, reduced production costs and improved product quality.

Technical cooperation activities are limited by the low levels of resources provided for by the Agreement.

The IOOC, however, has always had the support of its main Member, the European Union, which not only pays a substantial proportion of its budget but also provides additional contributions covering representative activities.

The IOOC also has the support of the Member countries of the European Union and of its other Member countries which make available infrastructure, human resources and know-how for the application of these programmes.

Finally, the IOOC has recently established close links with the Common Fund for Commodities as stipulated in the text of the Agreement. The IOOC was one of the first international commodity organisations to present and obtain approval for a Project for Research and Development for the General Improvement of the Olive, in the framework of the operations of the Second Account of the Common Fund. The main objective of this Project which has a duration of three years (1994-96) is the improvement of productivity of the olive assets in the developing countries that are Members of the IOOC through the obtention of new varieties to meet the demands of more competitive modern olive cultivation.

POLICY ON QUALITY

The 1986 International Agreement on olive oil and table olives as extended and amended in 1993 and 1994 establishes under its article 26 entitled «Designations and definitions of olive oils and olive pomace oils» the policy of the Members on the matter of standardisation of the market for olive oil, olive pomace oil and table olives. This covers the adoption of international rules relating to the quality of products on the market and the control of international trade.

Under the terms of Article 29 of the Agreement, the Members undertake to take any measures, in the form required by their own national legislation, that will ensure the application of the principles and provisions of the following articles:

- 25 «Use of the designation 'olive oil'»
- 26 «Designations and definitions of olive oils and olive, pomace oils»
- 28 «Indications of source and appellations of origin»

Under the terms of Article 33 of the Agreement, the Members also undertake to ensure the application of the principles and provisions of Article 31 «Designations and definitions of table olives».

These compulsory principles and provisions in international trade are also recommended for domestic trade. Members undertake to prohibit and suppress in both domestic and international trade the use of designations not complying with these principles. Article 36 of the Agreement for the Standardisation of the market for olive oil and olive pomace oil, also stipulates that the IOOC shall take any measure it considers useful to eliminate unfair competition in international trade even on the part of non-Member States or nationals from these States.

These principles and provisions as laid down in articles 25, 26, 28 and 31 of the Agreement are also given in:

- the Trade Standard for olive oil and olive pomace oil
- the unified quality Standard to be applied to table olives in international trade.

In line with its policy for improving and monitoring quality and quality control, the International Olive Oil Council sponsors the procedure for voluntary control as agreed on by the associations of exporters and importers of olive oils and olive pomace oils on the markets on which the IOOC is carrying out promotion campaigns.

The Associations signing these agreements for the control of olive oils and olive pomace oils on these markets undertake to respect the control procedure on labelling and conformity of the oils analysed by the IOOC-accredited laboratories to the purity and quality parameters adopted by the IOOC which are periodically revised to keep up-to-date with technological and scientific progress. They also undertake to recommend that their members comply with the rules adopted by the IOOC and any repeated irregularities are to be reported to the appropriate authorities.

THE TRADE STANDARD FOR OLIVE OIL AND OLIVE POMACE OIL

This Trade Standard fixes for each designation of olive oil and olive pomace oil on the market certain minimum criteria for purity and quality. It also lays down rules on hygiene, packing and labelling and recommends the methods of analysis to be applied for the determination of the various criteria stated in the Standard.

THE UNIFIED QUALITY STANDARD FOR TABLE OLIVES ON THE INTERNATIONAL MARKET

This Standard describes and defines the various types of table olive on the international market as well as the most representative trade preparations. It lays down rules concerning olive size, quality classification, tolerance for defects in each type, hygiene, packing, authorised additives and processing aids, labelling and the recommended methods of analysis.

PHYSICAL AND CHEMICAL ANALYSIS

In its Trade Standard for olive oil and olive pomace oil, the International Olive Oil Council recommends the application of methods for the determination of each of the criteria covered by the Standard. These methods have shown good repeatability and reproducibility and some of them have been finalised and adopted by the ISO or the IUPAC. They have also been tested by the group of experts from laboratories and institutes that collaborate with the IOOC in the study of methods of analysis for olive oils and olive pomace oils.

Other methods that have been drawn up nationally and have been seen to be applicable to the analysis of olive oil have been adopted by the IOOC such as the method for the theoretical calculation of ECN 42 triglyceride content, methods for the determination of the content in steroidal hydrocarbons, stigmastadienes and other hydrocarbons. In addition, other methods have been drawn up as part of the collaboration organised by the IOOC and adopted after being seen to have acceptable repeatability and reproducibility. This is the case with the Method for the Organoleptic Assessment of Virgin Olive Oil and the attached standards for sensory analysis: General basic vocabulary, Glass for oil tasting, Guide for the installation of a test room, General methodology for the organoleptic assessment of virgin olive oil, Guide to the selection, training and control of qualified tasters of virgin olive oil.

IOOC ACCREDITATION OF CHEMICAL ANALYSIS LABORATORIES AND TASTING PANELS

Recognition by the International Olive Oil Council of the quality of laboratories for analysis with experience in olive oils and olive pomace oils has always been necessary in order to officially apply the IOOC-recommended methods of analysis for the monitoring of olive oils, especially those being put up for sale on the international market.

Since it was first set up, the International Olive Oil Council has been granting accreditation to any laboratories showing that they have suitable installations, experienced staff and correct analytical findings. These laboratories are periodically inspected and, if necessary, training courses are offered to their chemists on the application of new methods.

The laboratories accredited by the International Olive Oil Council may be approached in settlements of international disputes on olive oil and olive pomace oils.

They may also be requested to carry out analyses as part of programmes for monitoring the olive oils and olive pomace oils being sold on certain markets. These programmes are applied voluntarily by certain associations of exporters and importers collaborating with the International Olive Oil Council to maintain and improve the quality image of olive oil on certain major importing markets.

After drawing up and adopting the method for the Organoleptic Assessment of Virgin Olive Oil in 1987, the International Olive Oil Council has made efforts to make this method known and to train panel supervisors and tasters in order for it to be applied correctly and uniformly. In 1991, the IOOC adopted an accreditation certificate for tasting panels which lays down the conditions for approving a panel and the obligations of those that obtain IOOC accreditation. The tasting panels accredited by the IOOC are also submitted to monitoring by the IOOC which periodically organises coordination meetings for the supervisors of accredited panels and those that have applied for accreditation.

Since sensory analysis is accepted as being the only way of ascertaining virgin olive oil quality, the efforts of the International Olive Oil Council have led to the creation of a very effective method that can be uniformly applied by tasting panels in any country.

POLICY FOR THE PROMOTION OF OLIVE OIL AND TABLE OLIVE CONSUMPTION

GENERAL CONSIDERATIONS

The legal basis for the Council activities in promotion is laid down in Article 44 of the International Agreement on Olive Oil and Table Olives, 1986, as extended and amended in the Protocol of 1993, which textually stipulates the following:

«Article 44

Programmes to promote the consumption of
olive oil and table olives

1. The Members contributing to the Promotion Fund referred to in article 10 undertake jointly to conduct generic promotional activities to expand world consumption of olive oils and table olives, on the basis of the use of the designations of edible olive oils as defined in article 26 and of table olives as defined in article 31.
2. Those activities shall take the form of educational and advertising campaigns and deal with the organoleptic and chemical characteristics of olive oils and table olives, as well as with their nutritive, therapeutic and other properties.
3. Within the framework of the promotional campaigns, consumers shall be informed about the designations, origins and sources of olive oils and table olives, care being taken to ensure that no quality, origin or source is either promoted or given prominence in preference to another.
4. The promotional campaigns to be undertaken under this article shall be decided on by the Council in the light of the resources made available to it. Priority shall be given to action in the mainly-consuming countries in which the consumption of olive oils and table olives is likely to increase.
5. The resources of the Promotion Fund shall be used in the light of the following criteria;

– the volume of consumption and the possibilities of developing existing outlets;
– the creation of new outlets for olive oils and table olives;
– the returns obtainable on the promotion expenditure.

6. The Council shall administer the funds allocated for joint promotion purposes. It shall prepare an annual estimate of receipts and expenditure relating to this promotion as an annex to its budget.
7. The technical execution of promotion campaigns may be entrusted by the Council to specialized bodies of its own choice.»

In line with the provisions of paragraphs 2 and 3 of this article, the promotional activities of the Council are based on the use of the generic designation «olive oil» and «table olives» without any bias nor emphasis on any specific origin or variety and without mentioning any trade name.

In events organised and carried out by the Council no reference is made to any specific brand of oil.

For the financing of these promotional activities, the Council has a basic fund for promotion of 500,000 ECU which is constituted as stipulated under article 19 of the Agreement.

«Article 19

Constitution of the Fund

1. The mainly-producing Members undertake to place at the disposal of the Council for each calendar year, for the joint promotion defined in chapter XIV of this Agreement, a sum of 600,000 United States dollars.
2. The above sum may be increased by the Council provided, on the one hand, that no Member's contribution is increased without that Member's consent and, on the other, that any alteration occurring in this connection in the shares referred to in article 20 shall require a unanimous decision of the mainly-producing Members.
3. The above-mentioned sum shall be payable in ECUs or in the equivalent amount of another freely convertible currency.»

However, in order to obtain more funds to extend promotion activities, Article 21 of the Agreement allows for the provision of voluntary contributions and donations to the Promotion Fund.

«Article 21

Voluntary contributions and donations

1. Mainly-importing Members may pay contributions to the Promotion Fund by special agreement with the Council. These contributions shall be added to the monies constituting the Fund as determined pursuant to article 19.
2. The Council may receive donations from Governments or from other sources for the joint promotion in question. Such occasional resources shall be added to the monies constituting the Promotion Fund as determined pursuant to article 19.»

This article allows the Council to carry out activities with much greater funds than those established in article 19.

The main contributor is the European Community and to a lesser extent the trade associations.

The amounts of the Promotion Fund stipulated by the Council in recent years have been:

1990	2,495,890.48 US$
1991	4,887,578.73 US$
1992	5,946,189.75 US$
1993	5,671,239.99 US$
1994	5,183,333.00 ECUS
1995	5,629,032.56 ECUS

PROMOTIONAL ACTIVITIES CARRIED OUT BY THE COUNCIL OVER THE LAST FIVE YEARS

Promotional campaigns in the United States of America, Australia, Japan and Canada

Since 1984 the Council has been intensifying its activities to promote olive oil in new markets with high purchasing power.

The first market of this type was the United States of America and the campaigns which started in 1984 are continuing.

Promotion campaigns were launched in Australia in 1990, in Japan in 1991, in Canada in 1994 and in Argentina in 1995.

Campaign strategy and activities

Promotional and information activities are basically of a «Public Relations» type and are directed at «opinion leaders» with a view to reaching consumers through them.

This group of «opinion leaders» have a direct influence on consumer opinion and habits and is made up of: media specialists in food, gastronomy and nutrition (TV, radio, the press), cookery book writers and publishers, well-known cooks and restaurateurs, experts in nutrition and dietetics, doctors and researchers.

The Council aims to establish constant and far-reaching contact with this group with a view to transmitting to them its messages and convincing them of the benefits of olive oil consumption.

The messages focus on the gastronomic aspects of olive oil and the effect of olive oil consumption on human health.

They also, in some cases, include economic, technical and historical information.

However, bearing in mind that olive oil is a basic ingredient of Mediterranean cuisine, the message is first presented through the promotion of Mediterranean cuisine. The use of olive oil is then encouraged in the national cuisines of these markets.

Contact is generally established with this group of «opinion leaders» by means of:

- Visits and individual invitations

  The Council experts and spokespersons regularly hold meetings in restaurants or in their working places with the «opinion leaders» to provide them with information individually.

  During these meetings they hand out unnamed samples and a wide variety of literature.

  This activity enables the Council to set up personal links which will help to arouse the interest of these people in the subject.

- Production and despatch of literature

  In order to give full support to these activities, the Council draws up and distributes all sorts of information.

  This mainly comprises leaflets, booklets, posters, articles, photographs, videos and cassettes.

  Every attempt is made to ensure that the content of the material is adapted to the mentality of the market for which it is designed.

  As well as distributing this material in the events in which the Council participates, mailshots are sent out periodically to a long list of «opinion leaders».

- Organisation of conferences, seminars and cooking demonstrations

This type of activity takes two different forms.

The first is organised within the markets themselves and the second within the Mediterranean countries.

Groups of «opinion leaders» are often invited to olive oil tasting sessions and to participate in brief conferences or seminars on Mediterranean gastronomy and the importance of olive oil.

During such meetings demonstrations are sometimes carried out by famous chefs on the preparation of Mediterranean or national dishes using olive oil.

This type of meeting that is organised periodically in several cities within each market enables contact to be made with a large number of people.

United States:

- Conference on «Florida as Crossroads: Olive Oil and the Cuisine of the New World», Florida, March 1991
- Conference on «From Asia to the Mediterranean: Cultural models for healthy eating», Los Angeles, September 1991
- Conference on «Foods, Choices 2000: Sustainable diets for the next century», Hawaii, July 1993

Australia:

- Gastronomic conference, olive oil tasting sessions, Sydney, June 1990
- Olive oil tasting sessions, Sydney, Melbourne, Adelaide, Brisbane, during 1991
- Olive oil tasting session, Brisbane, April 1992 and Sydney, June 1992
- Symposium on Mediterranean cuisine, Melbourne, September 1992
- Promotion of Mediterranean cuisine, Sydney, September 1992
- Tasting sessions on olive oil and table olives, Brisbane, Sydney, Melbourne, Adelaide, October 1992
- Promotion on «Food from the Mediterranean», Brisbane, March 1993
- Public Forum on «Mediterranean and Traditional Diets», Canberra, March 1993
- Tasting session on olive oil and table olives, Brisbane, March 1993
- Symposium on «Health Implications of Diets of the Mediterranean», Adelaide, September 1993
- Seminars on table olives, Sydney and Melbourne, April 1994
- Tribute to the cuisines of Italy, Sydney, April 1994
- Symposium on the Mediterranean Diet, Perth, August 1994.

Japan:

- Conference on «Health and Nutrition Aspects of the Mediterranean Diet», Osaka, April 1992
- Conference on «From Asia to the Mediterranean: Traditional, Healthful Diets in the 21st Century», Osaka, October 1992
- Conferences on «The Traditional Diet of the Mediterranean» and olive oil tasting session, Tokyo and Osaka, April 1993
- Seminars on table olives, Tokyo and Osaka, March 1994
- Seminar on olive oil and tasting session, Fukuoka, June 1994
- Seminar on olive oil and tasting session, Nagoya, July 1994

Canada:

- Symposium on «Mediterranean Diet and Olive Oil», Toronto, Ontario, June 1994.

The second type of activity takes into account the fact that olive oil promotion has to be carried out within the framework of Medtierranean gastronomy and therefore the Council holds information events in the Mediterranean countries. The aim is to invite, with the collaboration of the «Oldways Preservation & Exchange Trust»

Foundation, important opinion leaders (media representatives, gastronomists, chefs, cookery writers and experts in nutrition) from the United States of America, Australia and Japan to gastronomic meetings in Mediterranean countries in order to inform them at close hand of the characteristics of the different cuisines in Mediterranean gastronomy.

During the event conferences, seminars, panels, demonstrations and tasting sessions are held on the gastronomy of the Mediterranean country in question.

Within this strategy, the Council organised and participated in the following gastronomic meetings:

- Greece. Porto Carras, October 1991
- Spain. Seville, Barcelona, Madrid, October 1992
- Turkey. Istanbul, October 1993
- Tunisia. Tunis, December 1993
- Italy. Rome, March 1994

Organisation of scientific meetings

In line with its strategy, the Council attempts to circulate as widely as possible the conclusions of scientific research carried out on the effects of the consumption of oils and fats (particularly olive oil) on human health.

It organises international scientific seminars, conferences and symposia for the medical community in each country.

These meetings constitute a scientific forum for the debate and publication of findings on the consumption of fats and oils.

The Council does what it can to ensure that these events are constantly reported in the media within the markets in question.

This type of activity allows the Council to keep in touch with all research being carried out in this field.

The Council has organised in recent years the following scientific meetings:

- United States:
  - IV International Colloquium on «Monounsaturated Fatty Acids», Boston, September 1990
  - International Conference on «The Diets of the Mediterranean», Cambridge, January 1993
  - Conference on «How to modify the eating behaviour of the Americans - Mediterranean Inspiration, American Interpretation», San Francisco, June 1994
- Australia:
  - Conference on «Olive oil and other dietary fats: their role in health and nutrition», Sydney, June 1990
  - Conference on «Monounsaturated fats in coronary pathology and other diseases», Melbourne, April 1991
  - Colloquium in Deakin University, South Australia, April 1991
  - Conference on «Monounsaturates and health», McLaren Vale, August 1991
  - Symposium on «Monounsaturated fats in coronary and other diseases», Brisbane, September 1991
  - Conference on «New Roles for Monounsaturates», Adelaide, March 1992
  - Conference on «Frying with olive oil», Melbourne, September 1992
  - Symposium on «The role of monunsaturates in the treatment of diabetes and other diseases», Sydney, September 1993
  - Conference on «New Findings in Australian Research on olive oil», Hayman Island, April 1994.
- Japan:
  - Symposium on «Monounsaturated oils in the prevention of cardiovascular pathology and other diseases», Tokyo, April 1991
  - Seminar on «Present and Future of Frying», Tokyo, October 1991
  - Symposium on «Mediterranean diet and multiple risk factors in cardiovascular disease», Osaka, October 1992
  - Symposium on «Monounsaturated fats in the treatment of diabetes», Tokyo and Osaka, April 1993
  - Conference on «The benefits of olive oil in the treatment of diabetes», Kobe, September 1994

Active participation in periodic meetings of certain associations in the restaurant sector

Considering that the Council's promotional activities largely take place in the area of gastronomy, efforts to develop contacts in the restaurant sector are being stepped up.

In the United States, the Council pays special attention to participating in the annual meetings of various associations within this sector.

Such meetings bring together a large number of professionals and provide an opportunity to make contact with a large number of experts and to distribute information on olive oil amongst a large, specialist audience.

Council participation in these events also involves the organisation of seminars, demonstrations and tasting sessions.

In recent years, the Council has attended the annual meetings of the following associations:

- American Culinary Federation
- International Association of Culinary Professionals
- National Restaurant Association
- Food Editors Convention

Within the United States of America, the Council also participates in the annual meeting of the «Public Voice for Food and Health Policy» which regularly brings together a large number of opinion leaders from the food and nutrition sectors.

The aim of this organisation is to orientate food and nutrition policy in the United States.

Organisation of «Media Tours»

In view of the importance of the mass media for transmitting messages to the general public, the Council organises «Media tours» in the United States, Australia and Japan.

The Council spokespersons (experts in nutrition and gastronomy) travel to various regions and participate in important TV and radio programmes on the subject of food, gastronomy and nutrition to inform on the gastronomic and nutritional aspects of olive oil.

During these tours, the Council arranges meetings with well-known media personalities to inform them on olive oil in informal discussions and tasting sessions.

These activities also facilitate contacts with important representatives of the mass media in several areas of the market.

Contacts with professionals in the sector and quality control

In order for its promotional activities to be effective, the Council collaborates with olive oil importers and distributors.

It holds regular meetings with the «North American Olive Oil Association» and the «Australian Olive Oil Association» to discuss problems and find solutions for them as well as to coordinate work on promotion in these markets.

Within the same framework and with the collaboration of these associations, agreements on quality control have been reached involving periodical sampling and analyses in the laboratories holding Council accreditation.

This makes it possible to carry out strict control of the olive oils sold on these markets and helps to achieve constant improvement.

In addition to collaborating with importers, «Marketing Seminars» are held to bring together exporters and importers in these markets with a view to exchanging points of view on any problems existing and to find ways of increasing outlets for exporters towards these markets.

Contacts with national administrations

The definitions of olive oils in the legislations of the United States of America, Australia and Japan do not coincide with the designations given in the Agreement. The Council therefore maintains permanent contact with the administration in these three countries with a view to harmonising local laws with the provisions of the Agreement.

Other events

The Council carries out additional actions that are closely related with the characteristics of the markets where they are carrying out promotional activities.

In the United States of America, an olive oil hot line was set up connected to Cornell University to answer queries of a gastronomic and scientific nature.

In the Japanese and Australian markets, the Council carries out «promotional activities at the points of sale». It hands out information and offers various products for tasting.

In these two countries, the Council also participates in the most important food fairs and conferences and organises sessions on Mediterranean gastronomy.

Collaboration with institutes and foundations

In its promotional activities, the Council aims to obtain collaboration and support from prestigious institutes and foundations of a non-lucrative nature, both public and private.

This collaboration generally takes the form of joint gastronomic and scientific events.

Some such entities are:

- In the United States:
  - Harvard University
  - Cornell University
  - American Institute of Wine and Food
  - Oldways Preservation and Exchange Trust
  - James Beard Society
- In Australia:
  - Australia Nutrition Society
  - National Heart Foundation
- In Japan:
  - Japan Heart Foundation
  - Japan Society of Nutritionists and Dietitians

Market research

The Council carries out regular market research with a view to entering new markets.

This activity helps the Council in launching its campaigns and in informing exporters on the situation in other promising markets.

In addition to market studies carried out in the United States in November 1981, April 1982, August 1983, May 1989, November 1990 and in Australia and Japan in 1989, more recently the Council has carried out the following market research:

- International research into the table olive sector, May 1989

- Turkey, May 1989
- Jordan, November 1989
- Syria, November 1989
- Nordic countries, October 1991
- Argentina, October 1993
- Canada, October 1993

Table olive promotion

In its promotional work on olive oil in the United States of America, Australia and Japan, the Council takes the opportunity to promote table olive consumption.

Since 1993, after producing sufficient promotional material (leaflets, booklets, posters and videos) on table olives, it intensified its efforts by organising sessions on this product alone.

These involved providing information for «opinion leaders» on gastronomic and nutritional aspects of table olives through conferences, demonstrations and tasting sessions.

Events were held as follows from 1993 to 1994:
- New York, January 1993
- Tokyo, March 1994
- Osaka, March 1994
- Sydney, April 1994
- Melbourne, April 1994

Olive oil events, production of material

The Council also carries out promotional activities outside the markets where it is launching campaigns, although on a smaller scale.

This initiative centres on the producer countries that are Council Members and takes the form of participation in fairs, conferences and seminars related to the olive oil sector, nutrition and Mediterranean gastronomy.

This activity allows the Council to contact in the Member countries the professional associations within the sector (trade, industry and producers) as well as official and private organisations linked to the olive oil and table olive sector.

Participation in these events permits the Council to find out the points of view of those responsible for the sector in the producer countries which helps in planning Council activities.

The following are the main activities in which the Council participated from 1990 to 1994:
- Greece:
  - · Seminar on olive oil quality, Thessaloniki, 17-19 May 1994
- Italy:
  - · Feria di Levante, Bari, 1-5 October 1992
  - · Feria di Genova, Genoa, 9-14 November 1992
  - · TECNOLIVO-94, Verona, 9-13 March 1994
  - · OLEUM, International olive oil fair, Florence, 19-23 March 1994
- Morocco:
  - · OLIVIADE-90 (1st world olive fair), Marrakesh, 14-20 May 1990
- Portugal:
  - · OLIVOMOURA-91, Moura, 9-12 May 1991
  - · III Fair on olive cultivation, Campo Maior, 8-10 May 1992
  - · 1st Portuguese Olive Oil Conference, Evora, 4-5 February 1993
- Spain:
  - · SIO-90 (Olive industry fair), Reus-Tarragona, 22-27 May 1990
  - · Sessions on olive oil in the Ateneo, Madrid, 3-4 December 1990
  - · EXPOLIVA, Jaén, 3-9 June 1991
  - · SIO-92 (Olive industry fair), Reus-Tarragona, 12-16 May 1992
  - · EXPO-92, Seville, Barcelona, Madrid, 1-11 October 1992
  - · EXPOLIVA, Jaén, 20-23 May 1993
  - · ALIMENTARES-94, Barcelona, 28 February - 6 March 1994
  - · SIO-94 (Olive industry fair), Reus-Tarragona, 24-28 May 1994
  - · Olive Fair, Montoro, Cordoba, 12-15 May 1994
- Turkey:
  - · Seminar on IOOC activities, Izmir, 5 November 1993
  - · International congress on the food industry in Turkey, Istanbul, 29 May - 3 June 1994

The Council is also constantly producing information and educational material (printed, audiovisual and for radio) for distribution in its own activities and to serve as a model in the markets where its campaigns take place.

Publication of findings of scientific research

In view of the importance of the findings of scientific research on the positive effect of olive oil consumption for human health, the Council organises and/or participates in scientific meetings (congress, conferences, symposia, etc.) within the Member countries.

These activities help to keep the medical profession in the Member countries up to date.

All sorts of scientific informational material (leaflets, books, etc.) are produced.

In recent years, the Council has organised and/or participated in the following scientific meetings in the Member countries:

- Greece:
  - Congress on nutrition, Thessaloniki, 20-22 May 1994
- Italy:
  - II National Congress of the Associazione Italiana di Nutrizione Clinica e Preventiva (AINCLEP), Naples, 14-16 October 1993
  - International Conference on the Mediterranean diet, Capri, 8 June 1993
  - Conference on the Mediterranean diet, Rome, 4 March 1994
- Morocco:
  - International Symposium on the biological value of olive oil, Marrakesh, 16 May 1990
- Spain:
  - I international course on advances in medical sciences, Las Palmas de Gran Canaria, 27 February - 6 March 1993
- Tunisia:
  - Colloquium on the nutritional characteristics of Mediterranean food regimes, Prevention of cardiovascular diseases, Tunisia, 30-31 October 1992
  - Medical conference on olive oil, Tunisia, 26 November 1993
- Turkey:
  - International symposium on nutrition and cardiovascular disease, Istanbul, 30 June 1992
- United Kingdom:
  - V International Colloquium on «Monounsaturated fatty acids», London, 17-18 February 1992

Scientific research

In 1994 the Council created a special fund to encourage and finance scientific research on olive oil.

A group of doctors and researchers set up by the Council directs and coordinates the research undertaken in this field.

Publication of the OLIVAE magazine

In order to inform the whole sector of the activities of the Council, a magazine is published every two months. This magazine is sent out to approximately 50 countries and gives up-to-date information on technical, economic and legislative matters and the promotional activities of the Council.

Joint promotional activities
between the Council and its Members

As from 1993, the Council initiated a new type of promotional collaboration with its Members involving joint activities.

The first case of such collaboration was the organisation with Italy of three different events from June 1993 to April 1994.

The first event to be organised was a visit to south Italy by 50 opinion leaders from the United States, Australia and Japan in June 1993.

The second event was an International Congress on Italian Gastronomy in Rome during the first week of March 1994.

This was attended by 60 opinion leaders from the United States, 20 from Australia and 20 from Japan, as well as 60 importers of food products from the United States, 20 from Australia and 20 from Japan.

The last activity within this joint collaboration was a meeting on Italian gastronomy in Sydney from 12 to 15 April 1994.

This initiative was mostly financed by the Italian administration and gave considerable support to the promotional activities carried out by the Council in the United States, Australia and Japan to promote «Mediterranean gastronomy».

ACTIVITIES CARRIED OUT BY THE EUROPEAN COMMUNITY TO PROMOTE OLIVE OIL AND TABLE OLIVE CONSUMPTION

F. Gencarelli

OLIVE OIL

The serious drop in olive oil consumption in Italy towards the end of the seventies led the Community not only to set up a system of aid for consumption but also to draw up community programmes to provide consumer information and other promotional activities for olive oil within the Community.

Owing to the fragmentation of trade in olive oil in comparison with other competing products, the Community considered that to eliminate the imbalance in the olive oil market it was necessary to support and complement private promotional activities with efficient action by the Community under the direct control of the Commission.

Council Regulation (EEC) no.1562/78, which introduced the system of aid for olive oil consumption, determined that a percentage of the amount of aid fixed annually by the Council should be allocated to the financing of information and promotion actions for this product. The Commission considered it necessary, in order to re-establish and maintain market equilibrium in the sector, to complement the system of aid to consumption with promotional programmes with 100% Community financing. The general rules governing this promotional activity were defined by Council Regulation (EEC) no.1970/80 and the technicalities of applying it were covered by Commission Regulation (EEC) Commission no.1348/81.

The promotional programmes include:
- collection and publication of scientific data on the nutritional qualities of olive oil amongst the medical and/or paramedical profession, the specialist press and final consumers;
- advertising and public relations actions in order to inform the public on the nutritional and gastronomic qualities of the various types of olive oil and on its many uses;
- market research with a view to extending demand for olive oil within the Community;
- scientific research, especially on the nutritional characteristics of olive oil[1].

Scientific promotion can take different forms such as the publication of written documentation, the production of films and audiovisual teaching material for schools and universities, the organisation of seminars on nutrition and food hygiene, and participation in scientific congresses.

The actions mentioned under b) are of many types. They include advertising campaigns in the media, especially television, gastronomic competitions, participation in food fairs and information sessions within schools. The actions can be chosen to meet the special requirements of the various markets where they are carried out.

The Community promotional campaigns are obviously of an institutional nature and relate to oil of any quality without indicating the brand or the national or geographic origin.

Measures to promote olive oil are managed directly by the Commission which, after informing the Council of the main lines of its programme, adopts a detailed programme, choosing through public tender the agencies that will carry it out. The Commission draws up the relevant contracts with the interested parties and supervises their work directly.

The Commission may be helped by specialist consultants, also chosen by public tender, in defining the programme, assessing the proposals made by the agencies, choosing the contracting parties and controlling the execution of the different actions.

Five promotional programmes have so far been carried out with a gradual increase in funding. The sixth programme which is to last two years was launched by the Commission in July 1994 and started in early 1995.

The first programme which took place from 1981 to 1982 covered five countries (Belgium, France, Germany, Great Britain and Italy) and cost a total of approximately 2.5 million ECUs.

The second programme (1983-84), costing about 3.7 million ECUs, covered ten of the Community Member states, although in the non-producer countries funding was rather limited.

The third programme (1985-86) with a budget of 4 million ECUs was applied in France, Germany, Great Britain, Greece, and Italy.

The fourth programme (1988-90), with a budget of 13.9 million ECUs, covered eight countries (Belgium, France, Germany, Great Britain, Greece, Italy, Spain and Portugal).

The fifth programme (1991-93), with a much higher budget (34.6 million ECUs) covered the whole Community.

The sixth programme which started up in 1995, has a budget of 30 million ECUs, and covers all the Member states. An additional budget is planned for the countries that joined the Community on 1 January 1995.

Although it is difficult to determine exactly the impact of the Community promotional campaigns on olive oil consumption, they have clearly helped to create a new, positive image of olive oil. It is now better known and more highly-esteemed, especially in the non-producer countries that habitually consume other fats and oils.

The recovery and conservation of high levels of consumption in the producer countries and the significant increase in demand in the other countries of the Community[2], in spite of fierce competition from other fats and oils and marked price differences, are very positive results that would have never have occurred without the Community promotion.

TABLE OLIVES

After surplus stocks built up in recent years as a result of insufficient consumer information and production that was out of step with market demand, the Community determined in its Regulation (EEC) no.1332/92 to assist in the financing of actions designed to develop table olive consumption in the Community. The condition was that such measures should be presented within the framework of programmes and carried out by the associations representing the various categories within the sector such as the organisations or unions of producers or dealers.

The actions to be financed should aim to:

- promote product quality, especially by means of market research and research into the production of olives with a low salt content;
- find new methods of packing;
- provide marketing advisory services for the operators in the sector;
- carry out advertising and public relations, including the organisation of and participation in fairs and other commercial events.

The promotional measures should not mention brand names and should not refer to any Member state.

Unlike the promotional campaigns for olive oil, measures to promote table olives are only partially financed by the Community (60% of the real cost) and this sum comes from the general Community budget (2 million ECUs per year) and not from a specific source. In addition, these measures are only indirectly managed by the Commission.

Management procedure in this sector is complex involving both the Commission and the national Administrations.

The programmes that have a maximum duration of three years are submitted by the professional or interprofessional associations to the national Administration which passes them on to the Commission with a reasoned opinion. After the programmes presented have been studied by the management committee, the Commission adopts the list of proposals that have been accepted for financing and passes this list back to the national authorities. The latter then proceed to draw up the contracts with the interested parties and ensure compliance with the terms of the contracts.

The technicalities of applying promotional measures are laid down in Commission Regulation (EEC) no. 3601/92 .

The first group of programmes to promote table olives was submitted by French, Greek, Italian and Spanish organisations and awaits Commission approval.

NOTES:

[1] Note that in recent years, research work in this sector has been included in the general scientific research programmes organised by the Community.

[2] During the period 1984-94, annual olive oil consumption in the four main producer countries (Spain, Italy, Greece and Portugal) increased from 1,305,000 t to almost 1,400,000 t. In the other countries of the Community, consumption more than doubled in the same period, from 33,000 t to 73,000 t per year.

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