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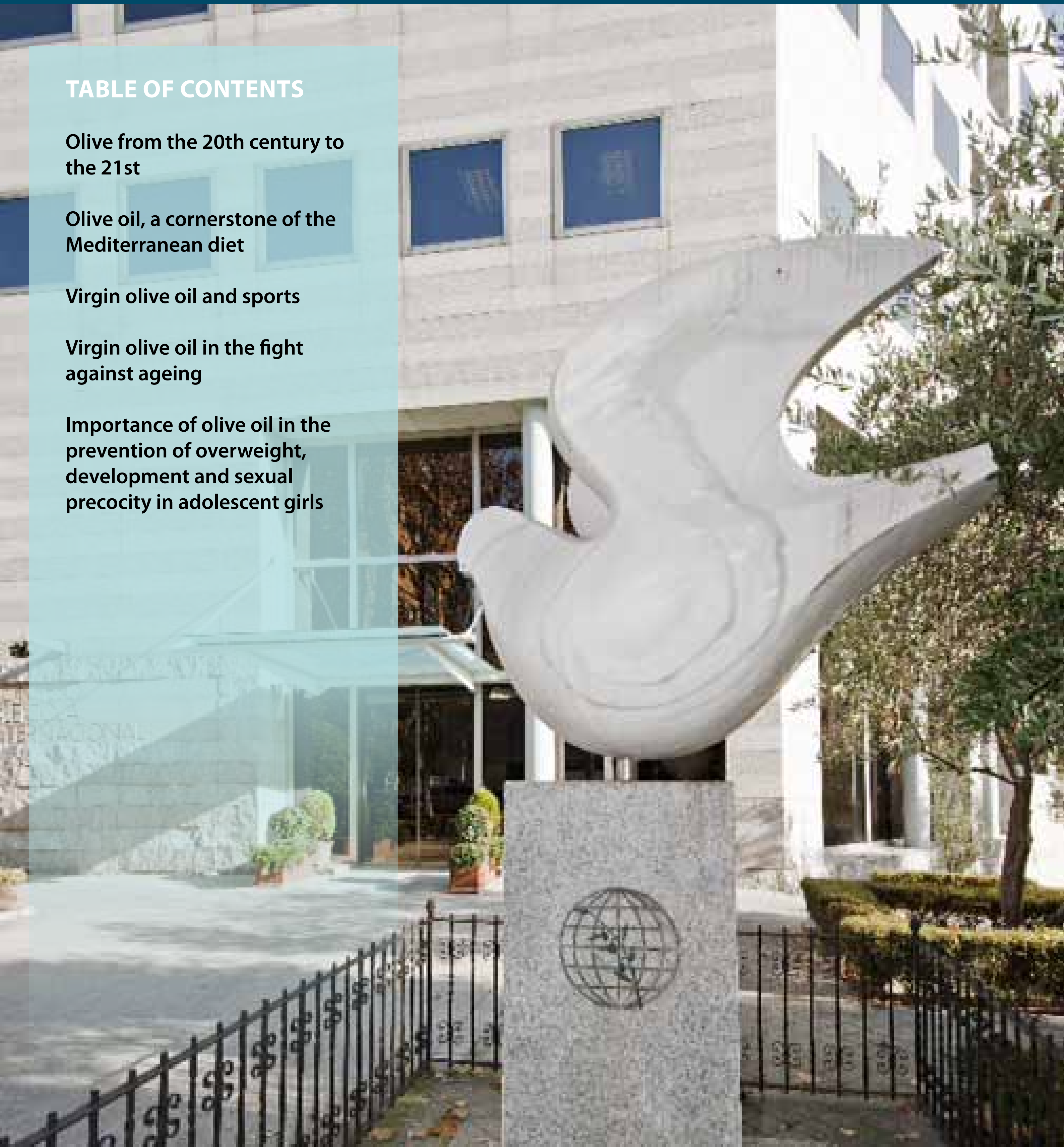

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EDITORIAL

Olive oil and the Mediterranean diet at EXPO 2015

This issue of OLIVAE is built around the central theme of EXPO MILAN 2015 – *Feeding the Plant, Energy for Life* – and more specifically around the EXPO project called Feeding Knowledge, aimed at cooperation in research and innovation on food security which seemed very relevant to this new edition of the journal.

Given the remit of the International Olive Council, this is our way of responding to the EXPO 2015 appeal for all agriculture and food institutions, organisations and agencies to become engaged according to their roles and responsibilities, whether it be in the improvement of food quality and security, the promotion of healthy, quality eating habits, the development of the concept of food security and disease prevention based on scientifically endorsed diets and practices, nutrition education and information, the creation of awareness of healthy lifestyles or the encouragement of food technology research and innovation.

The *2005 International Agreement on Olive Oil and Table Olives* is the current charter of the International Olive Council. Its general objectives include two lines of action considered to be essential by the member countries, namely:

> *"… To undertake activities fostering a better understanding of the nutritional, therapeutic and other properties of olive oil and table olives;*
> *… To maintain and amplify the role of the International Olive Council as a meeting point for all the operators in the sector and as a world documentation and information centre on the olive tree and its products."*

This issue is meant to respond to these objectives of the Agreement and simultaneously to join in the celebration of a worldwide event.

The role of olive oil as a cornerstone of the European diet is now firmly established across the globe. In 2010, the Mediterranean diet was included by UNESCO in its list of mankind's intangible cultural heritage and has deservedly become synonymous with healthy eating and wellbeing. The International Olive Council has always given pride of place and support to this diet and keeps close track of relevant research. For instance, the first International Mediterranean Diet Conference at which the now-famous Mediterranean Diet Pyramid was unveiled was held in Cambridge (Massachusetts) in 1993 with IOC sponsorship. Firmly convinced that olive oil fitted in perfectly with this concept, the Council had no hesitation in sponsoring two further conferences, one in Cambridge in 1998 and the other in London in 2000.

In the intervening years, scientific research has made steady progress, generating a growing body of conclusions on the biological, nutritional and health-promoting properties of olive oil. According to reports in ExpoNet, the official EXPO magazine, the first "nutraceutical" extra virgin olive will soon be on the market. This term is recognised Europe-wide and means that the oil can also be sold in pharmacies. Recently, a congress held on the Greek island of Zakynthos highlighted the "pharmaceutical" and therapeutic properties of certain types of extra virgin olive oils, attributable to their content of a specific compound called oleocanthal, which appears to have the same anti-inflammatory properties as ibuprofen. *In vitro* tests conducted so far have shown that 4 tablespoonfuls of oleocanthal-rich extra virgin olive oil are the equivalent of 250 mg of ibuprofen but do not have the side effects of this synthetic anti-inflammatory drug. And oleocanthal may even have anti-cancer properties. The International

Olive Council has always championed this concept of olive oil = health, but without reducing it to a mere functional food. Since its creation, it has worked hard to distribute proper scientific data to prove the healthiness of olive oil and to educate consumers about its health-promoting attributes.

This was the same thinking behind the Council's decision to convert its own official communications tool, i.e. OLIVAE, into an exclusively scientific journal that makes room for articles from all the sciences that research into the olive and its produce.

This issue opens with a review of how olive growing has evolved over the last century, followed by scientific articles on the role of olive oil in Mediterranean eating habits and its antioxidant protective role in elite sports. Other articles focus on its outstanding properties in the prevention of overweight or precocious sexual development in adolescents.

I would like to end by saying a big thank-you to the team of doctors who so generously offered to contribute unpublished articles for this issue that provide further proof that olive oil is a true source of energy for life.

Jean-Louis Barjol
Executive Director

Olive oil and health

Prof. Julio César Montero

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Chronic, non-communicable diseases (NCDs) are a top public health concern. Obesity, diabetes, high blood pressure, cardiovascular disease and cancer are the best-known of these diseases although the list also includes fatty liver disease, dyslipidaemias, osteoporosis, depression and Alzheimer's disease.

These diseases are quite recent in the history of mankind and have only been studied for a relatively short time. Consequently, it can be accepted that the impact of hitherto non-existent environmental factors on genetic factors prepared for other stimuli is a contributing cause.

Since nutrients and other components ingested through food are chief environmental factors, diet is one of the key mechanisms behind environment–genetics interaction.

Concurring with these hypotheses, population studies reveal that more traditional eating patterns featuring a high predominance of staple foods with little or no culinary preparation or processing are associated with lower NCD incidence. These traditional diets are frequently acknowledged to be beneficial in terms of what they supply and/or prevent and are connected with a longer, healthier life. The Mediterranean diet is one conspicuous example and figures pre-eminently amongst the eating patterns to be recommended at world level.

One of the goals of science is to determine irrefutably the nature of the "secret benefits" of the Mediterranean diet versus other diets. The Mediterranean diet features many highly beneficial combinations of foods in daily intake while other kinds of diets comprise several foods or combinations that may be harmful on their own or when consumed in excess or prepared in certain ways.

The Mediterranean diet is based on vegetables, olive oil (especially extra virgin olive oil), legumes, dairy products, fresh fruit, nuts, a moderate amount of meat and a limited, optional intake of wine. It also features a low intake of added sugars and processed foods incorporating high-calorie fats, all of which goes to make it one of the world's healthiest diets.

Although the composition of the Mediterranean diet is not identical in all the areas where it is consumed, its benefits do appear to be identical. Thus, the peoples of Spain, Italy, Greece and elsewhere probably share the same "health-promoting factor" in their diet, in which olive oil – and especially extra virgin olive oil – has a prominent position owing to its distinctive composition of polyphenols and antioxidants.

According to the scientific evidence available, the secret of the health benefits of olive oil, especially as regards glucose metabolism in diabetics, might lie in the fatty acids it contains, the substances it carries or a combination of the two or their interaction with other components in the diet. Could it be its abundance of omega 9 fatty acids, or its lower content of omega 6 fatty acids compared with other oils? Could it be the fats it replaces? Perhaps its wonderful flavour and aroma encourage people to eat healthy foods as a part of a diet in which the nutrients as a whole explain the mystery of this "healthy eating pattern".

While science comes up with the definitive answer, the Mediterranean diet imbued with the delicious flavours of olive oil is emblematic of the much-sought healthy interaction between genes and environment.

Scientific introduction to issue 121 and acknowledgements

Acknowledgements

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Consultant, Endocrinology, Metabolism and Nutrition
Europe representative, Latin American Federation of Obesity Societies (FLASO)

Since time immemorial, the peoples in the countries around the shores of the Mediterranean have enjoyed a longer and better quality of life with a lower incidence of cardiovascular events and lower rates of obesity, diabetes, dyslipidaemias, certain types of cancer and other conditions thanks to their diet. In fact, the term Mediterranean diet has become synonymous in its own right with a healthy, balanced diet which has anti-inflammatory and anti-oxidative properties. It has come to be viewed as an insurance policy against virtually all the conditions that make up the much debated – but not debatable – metabolic syndrome characterised by abdominal obesity, high triglycerides, low HDL cholesterol, high LDL cholesterol, high blood pressure, insulin resistance, increased coagulation and its ensuing cardiovascular risks, and diabetes mellitus.

All the latest scientific literature on the subject corroborates that olive oil, particularly extra virgin olive oil, is the cornerstone of the Mediterranean diet in which it plays a key role owing to its ability to decrease, prevent or overcome many of these risk factors to health and life. But what we did not know until only recently was that the **quantity** of extra virgin olive oil can boost these advantages dramatically, as has been demonstrated in the PREDIMED trial in which patients were administered 54 litres of extra virgin olive oil per year.

Coinciding with EXPO MILAN 2015, which opened in May of this year and will focus on the central theme of *Feeding the Plant, Energy for Life* until it closes in October, the International Olive Council thought it would be a good idea to dedicate this issue of the journal to the array of nutritional and medical benefits of olive oil and so make them known to the scientific community and general public.

My team and I appreciate the vote of confidence on inviting us to write articles about the fascinating properties of this liquid gold. In this issue we will address very interesting medical aspects ranging from the role of olive oil in sports nutrition and the Mediterranean diet to the effects of a shortage of olive oil on the development and sexual precocity of teenagers.

In future articles we will explore other facets of this key food such as its use in healthy food preparation and the benefits of specific cooking methods and its therapeutic properties in preventing mental decline, specific types of cancer and other diseases. The authorship of the articles will be more global, with contributions from experts in Europe, North Africa, the United States and Latin America.

We hope you enjoy reading this issue as much as we did writing it.

Olive from the 20th century to the 21st

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The olive industry entered the 20th century mostly as a traditional dry land set-up and olive orchards were cultivated accordingly. Most commercial orchards were planted in an organized row design and some continue to be so until the present day in traditional growing regions (Fig. 1).

Figure 1

The variation between trees in large mono-varietal orchards led to the advent of clonal selection to increase uniformity in future plantations. Although initially fragmented, clonal selection increased considerably in the 1950s on the basis of morphological criteria, and in the last 20 years performance has been further enhanced by the development of molecular identification methods (Fig. 2).

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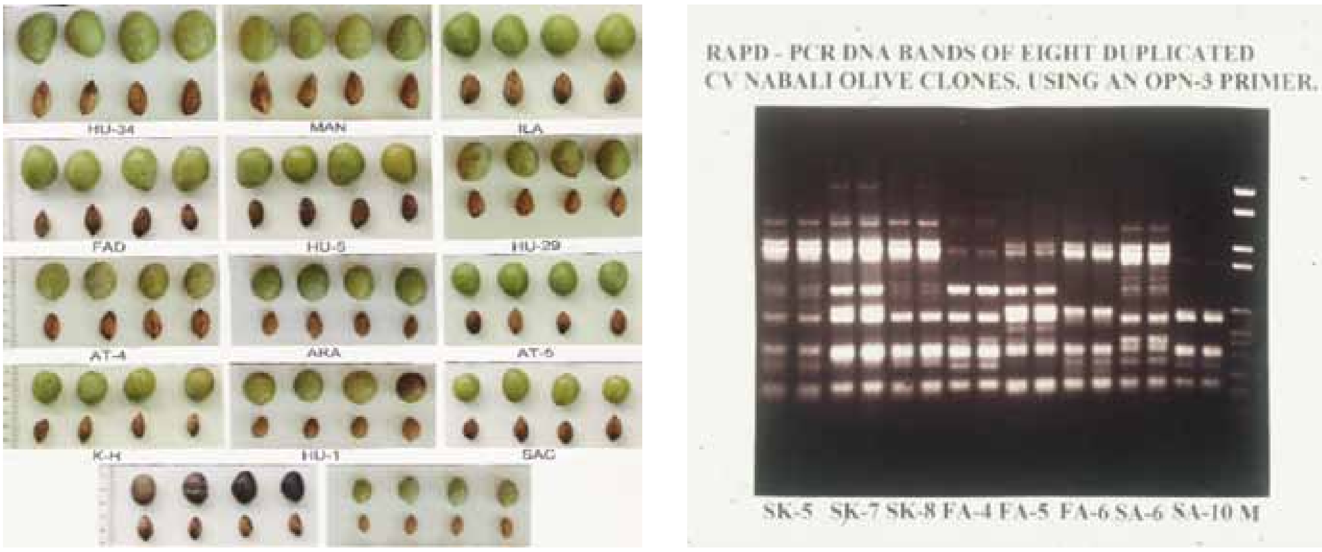


Figure 2

Interestingly, table olives were grown under intensive irrigated conditions in limited locations such as the United States and South Africa, as well as Israel in the 1930s (Fig. 3).

Figure 3

In the middle of the 20th century the economic changes brought about by the shortage and cost of labour in some of the major olive producing countries, particularly for oil extraction, triggered the development of methods to facilitate olive harvesting by chemical and mechanical means. Different approaches were tested and various types of trunk shakers became the major harvest aid in both traditional and newly planted intensive orchards supplying crop for the olive oil industry (Fig. 4).

Figure 4

Intensive research on the chemistry of olive oil started relatively early in the 20th century, particularly with the development and introduction of new centrifugal and similar oil extraction methodologies. These methods revolutionized the efficiency of the oil extraction industry and in the last 30–40 years have gradually become the sole system used in all large-scale commercial operations and many medium and small ones as well. In recent years, the processing and chemical potential of oil extraction from de-stoned olives has come under fresh review.

Generally, the first half of the 20th century was mainly based on morphological developments while the second half was based on physiological research which predominated in the development of olive growing.

The strong alternate bearing pattern of most olive cultivars became of major concern and the subject of many studies. The nature of bud differentiation as influenced by temperature and yield history and the influence of these two factors on tree metabolism were established, as was the involvement of defined changes in leaf protein and specific polyphenol content related to reproductive bud differentiation (Fig. 5).

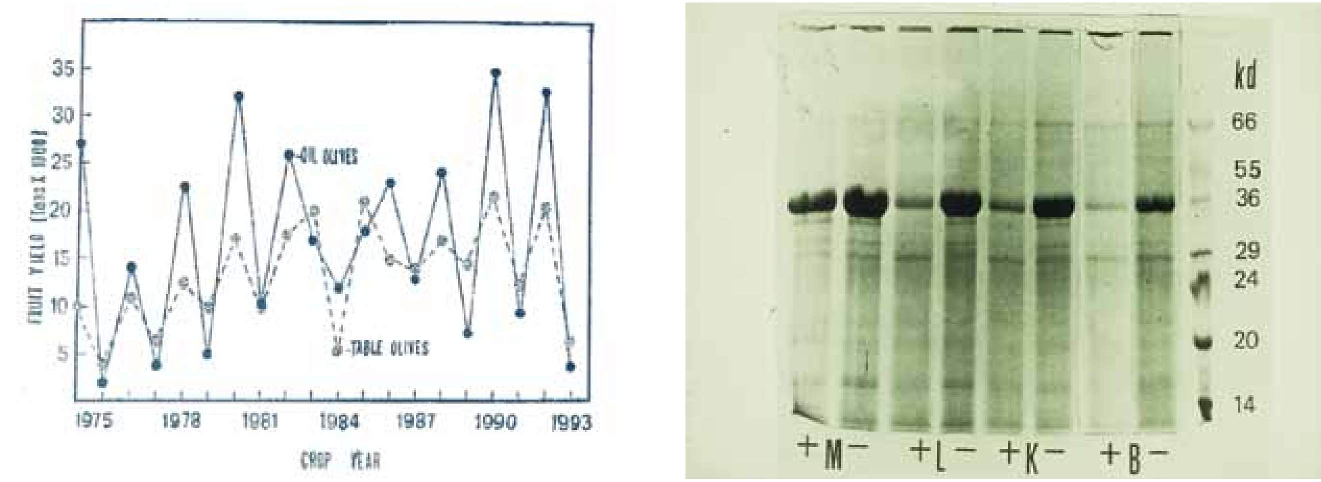


Figure 5

Various models have been published suggesting the mode of action leading to alternate bearing. The interaction between abiotic and induced biotic changes of metabolic pathways, mineral nutrition and hormonal control have all been incorporated into the models but no clear understanding or reliable control has yet been achieved. Research continues into ways of controlling alternate bearing and draws extensively on recently developed and newly developing genomics methods based on molecular gene activation at different stages of the olive tree fruit production cycle. Preliminary results are gradually becoming available and might lead to control of the annual level of fruit production (Fig. 6)

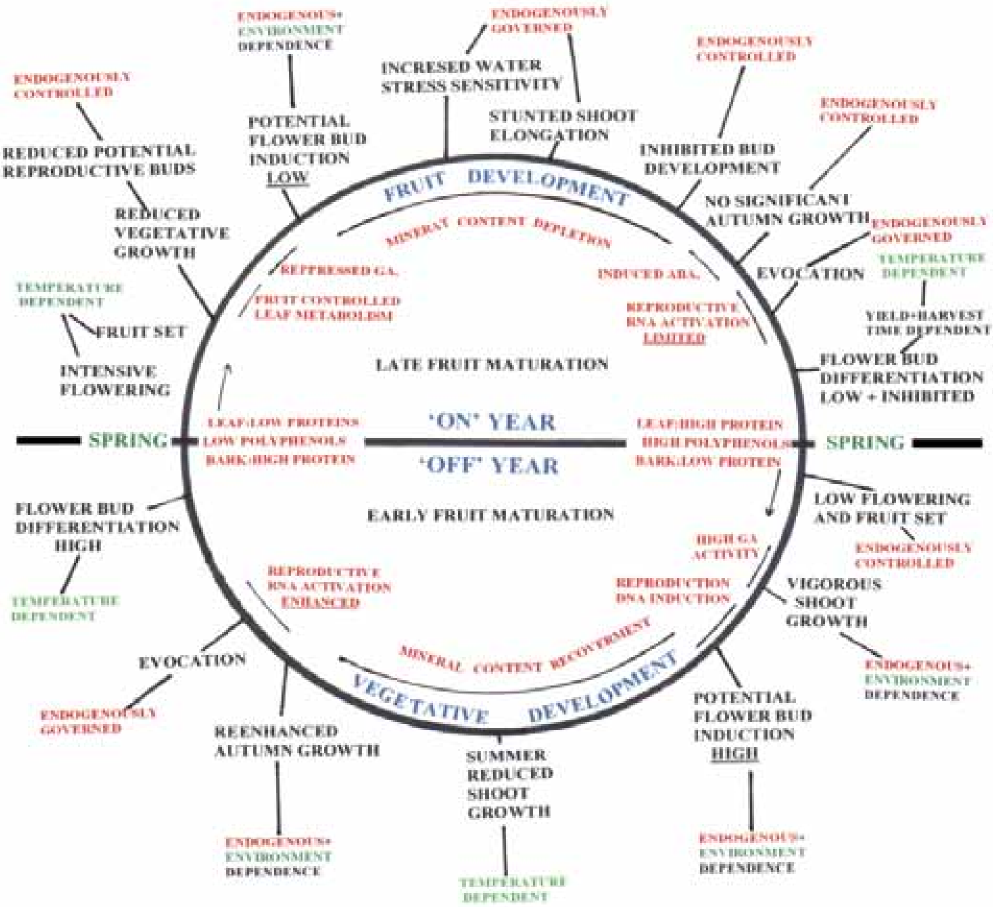


Figure 6

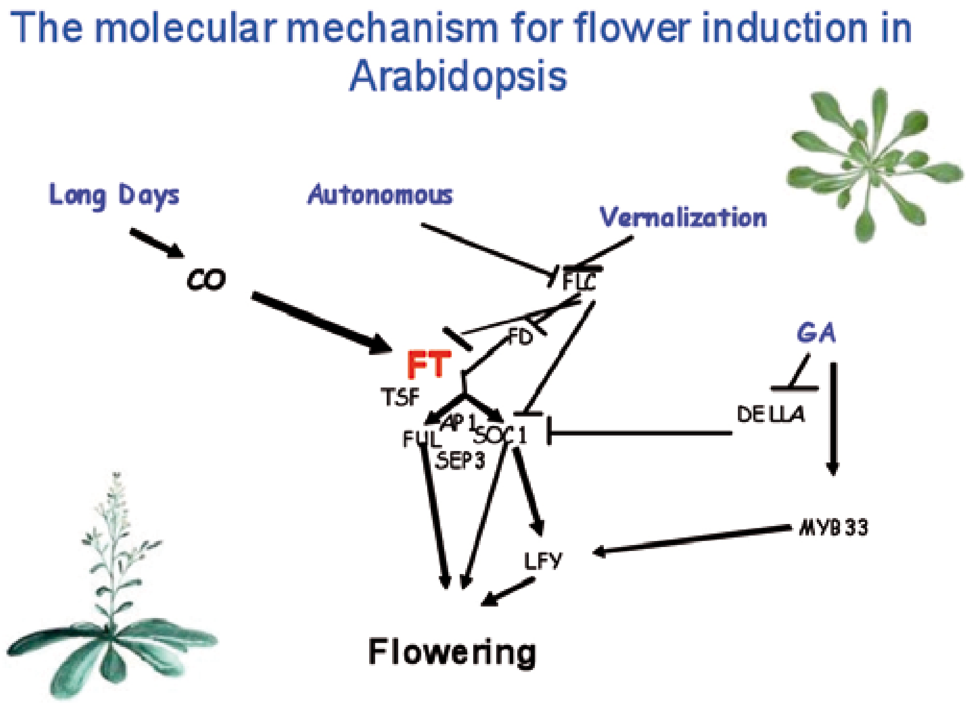


Figure 6 (contd)

Another major revolution in the productivity of oil-olive orchards started in the middle of the last century with the introduction of irrigation which was shown to multiply oil yield with only a minor effect on oil composition. Furthermore, the application of complementary irrigation in many olive growing regions deficient in fresh water was made possible by studies demonstrating the opportunities for using brackish and recycled water for this purpose. Although research and development in this subject area is still partly underway, the higher production it helped to achieve pushed the olive oil industry towards the 21st century and made olive oil an economically important commercial commodity in agricultural production and trade (Fig. 7).

Figure 7

Figure 7 (contd)

Even so, many of the traditional local cultivars that had been selected for generations for their adaptability to abiotic limiting conditions did not respond sufficiently to the "luxury" growing conditions. Thus, breeding programmes were undertaken parallel to the introduction of irrigation in order to develop new varieties more responsive to the new cultivation approach. The breeding that commenced in the second half of the last century was rather limited at the start due to the long juvenile period of olive seedlings, but this problem was resolved about 40 years ago by a surge of classic olive breeding in most traditional olive growing countries. The release of the first efficient cultivar and information about the efficiency rate of some traditional cultivars, combined with the methods available for harvest mechanization and the dissemination of the favourable health effects and consequential economic value of olive oil, prompted the massive development of the olive oil industry in regions and countries without a tradition of olive growing until then (Fig. 8).

Figure 8

Figure 8 (contd)

This expansion and the need to make olive oil production more cost-effective led to the development of new planting and growing systems such as the high-density hedgerow system in which the olives are harvested by overhead harvesters similar to those widely in use for grapevine. This growing system had been tried unsuccessfully for table olives in Israel about 40 years ago, but was later developed successfully in Spain and is now used commercially in the olive oil industry. Extensive research continues into the suitability of this labour-saving system for different growing conditions and environments. Subjects such as planting distances, training, pruning, sustainability and the adaptability of old and newly bred cultivars are being widely investigated (Fig. 9).

Figure 9

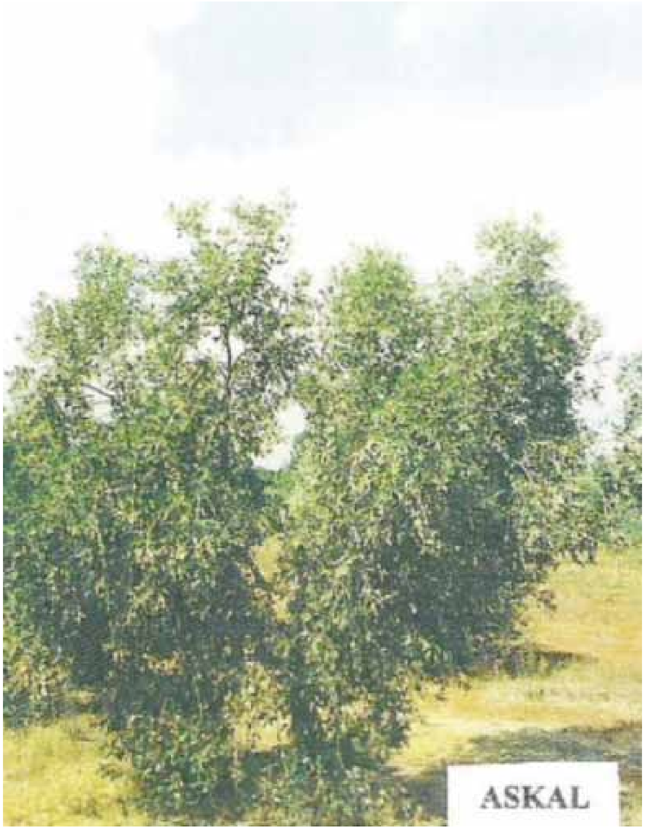


Figure 9 (contd)

About 40 years ago, another step of great significance to the olive oil industry was taken when the International Olive Council first engaged in creating awareness of olive oil quality and it started to develop quality standards which were gradually accepted by the world trade and are now in demand by the consumer public worldwide. Professional organoleptic tasting based on positive and negative attributes defined as clearly as possible became an official part of the quality standards and olive oil grading. These standards are systematically revised as new, more accurate analytical methods emerge. Awareness of quality standards and research received a major boost from the use of new-bred varieties in the recent new olive orchard systems and in the specific environmental conditions of large-scale orchards in new olive growing regions, particularly those without a former tradition of olive production. The changes that occur in the composition of olive oil produced from fruits growing under different environmental conditions has also led lately to studies characterizing these differences and the development of specific regional Protected Designations of Origin (PDOs) or Protected Geographical Indications (PGIs), which it is hoped will bring future commercial benefits for such oils (Fig. 10).

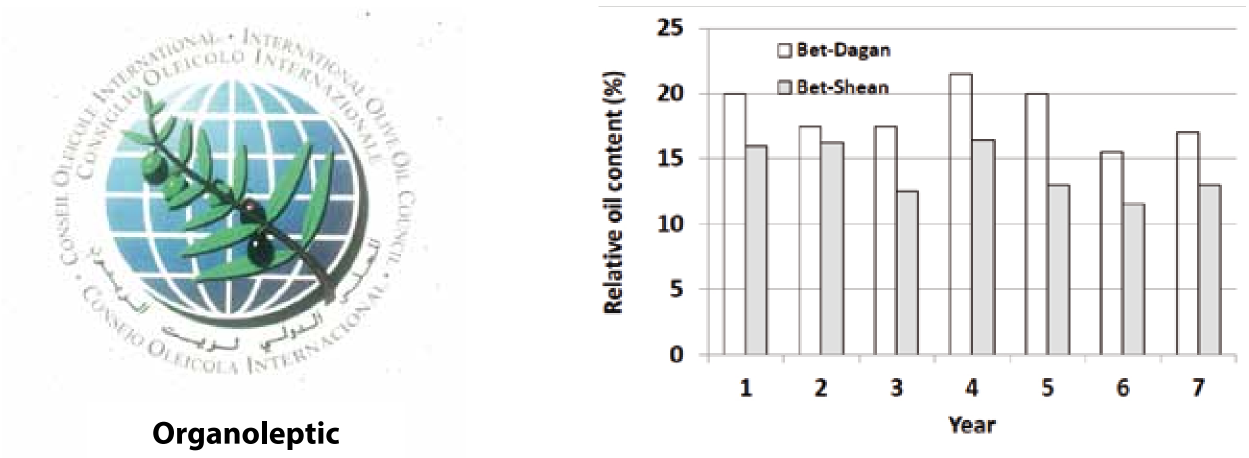
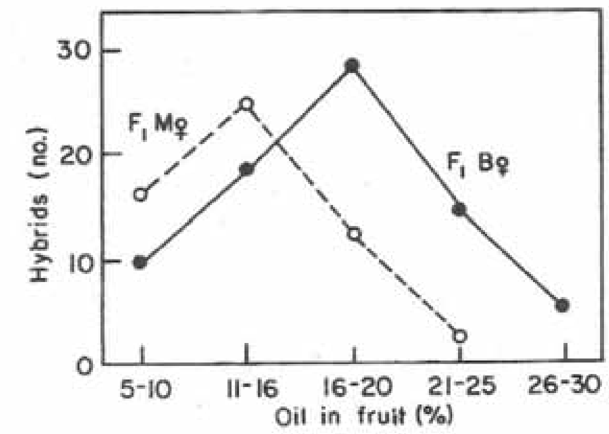
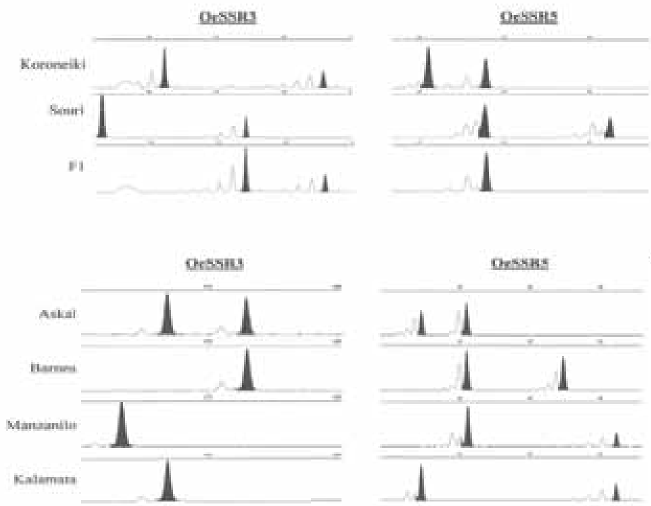


Figure 10

The classic breeding work that began in the second half of the 20th century also helped to build up genetic data that indicated some dominant and recessive traits in olive heredity. The potential heredity of the female genitor was found to dominate partially over that of the male, for instance in the fruit oil content and fruit shape of the progeny and to a lesser extent in leaf size although not in rooting ability. This helped to pave the way to gene identification by means of relatively new molecular methodologies such as simple sequence repeat (SSR) and single-nucleotide polymorphism (SNP). The recent development of these methodologies has been instrumental in verifying the male genitor of new cultivars and in grouping cultivars according to their genetic relation, origin and distribution. The present ability to determine the origin of the male genitor is critical for establishing suitable, efficient cultivar combinations for pollination purposes (Fig. 11).





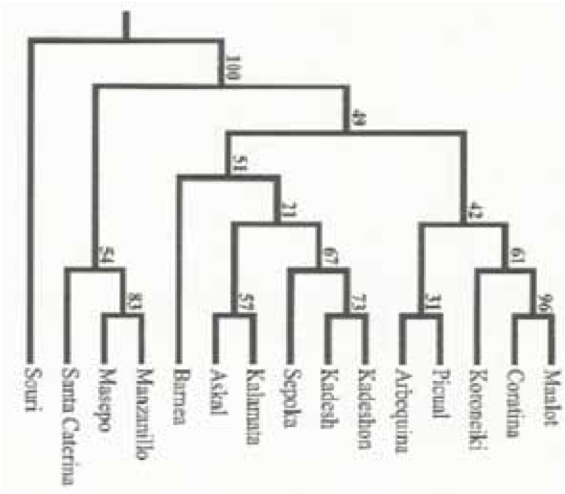


Figure 10 (contd)

North

Site name	Code
Azeka	AZK
Bet Nir	BNR
Kamonim	KAM
Ashkelon	ASH
Hadid	HAD
Makura	MAK
Rama Isa	RAI
Rama Raik	RAR
Qalqiliae Sinieria	QS
Amazia	AMZ

South

Boker Mountain	HB
Ovdat dryriverbed)	NO
Ramat Matred	ZM
Wadi Zeitan	WZ
Nahal Lavan	NL
Katef Nitsana	KN
Nahal Mitnan	MIT

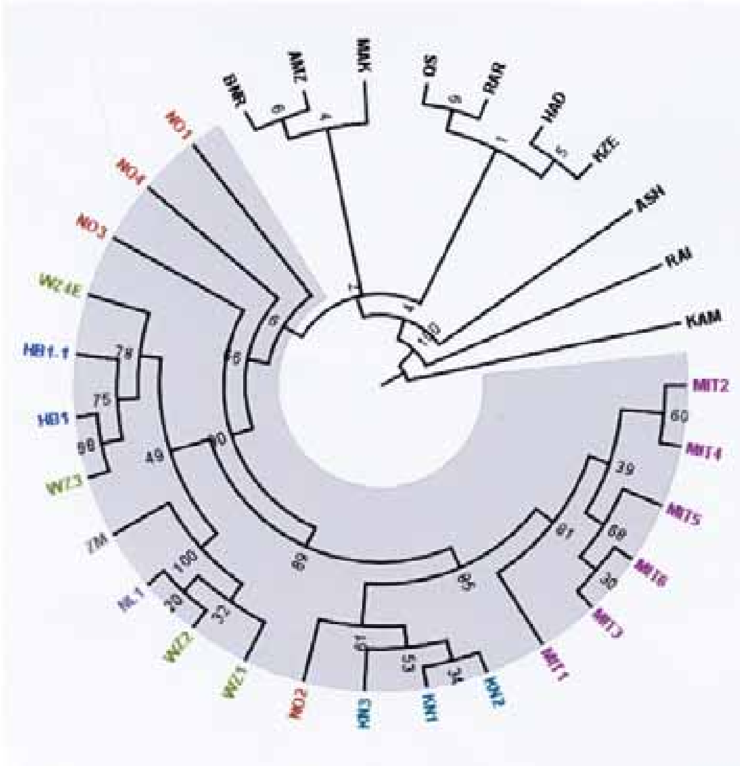


Figure 11

At present, some tools are already available while others are being developed to create genetic markers to serve as the basis for the future development of a more efficient and healthy olive industry. Currently, the most important approach for the future development of the olive industry is, and should be, to identify defined genetic markers for the recognition of specific required traits. Breeding for disease and pest resistance is of the utmost importance not only for the benefit of growers but also to minimize environmental pollution. As early as 20 years ago, genetic differences were identified between cultivars sensitive to olive leaf spot and resistant cultivars developed by breeding but the marker was not genetically specific enough. Although cultivars are known to be partially resistant to other pests and diseases such as *Verticillium Agrobacterium*, *Spilocaea,* olive fly etc., no genetic markers pointing to the gene combination involved are yet available (Fig. 12)

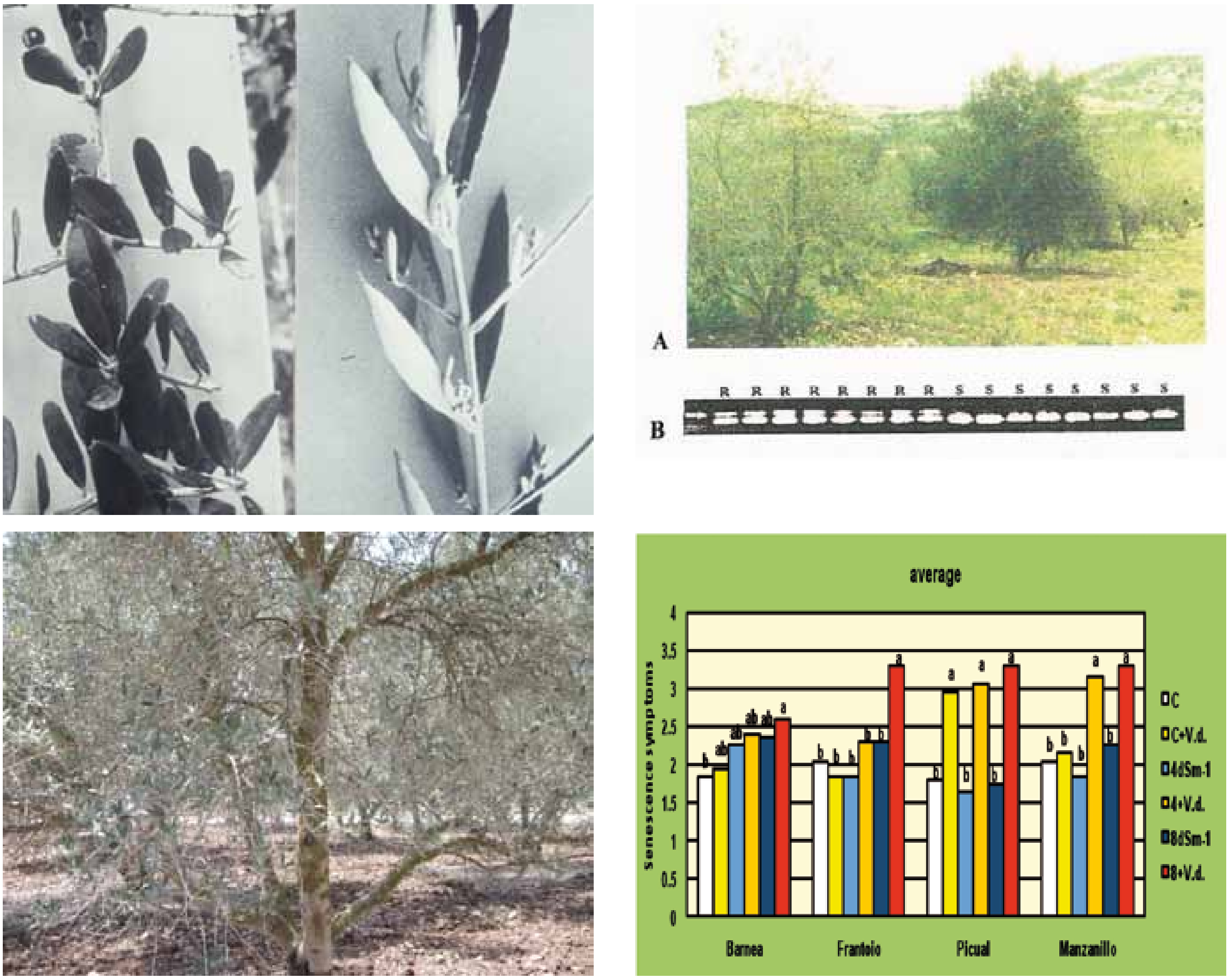


Figure 12: Top: *Spilocaea;* Bottom: *Verticillium*

The expression of such molecular markers should clearly describe the genes involved and their location in the genome but in some cases expression could also be by a physiological response such as in tissue culture or indicator plant systems or specific responding antibodies (Fig. 13).

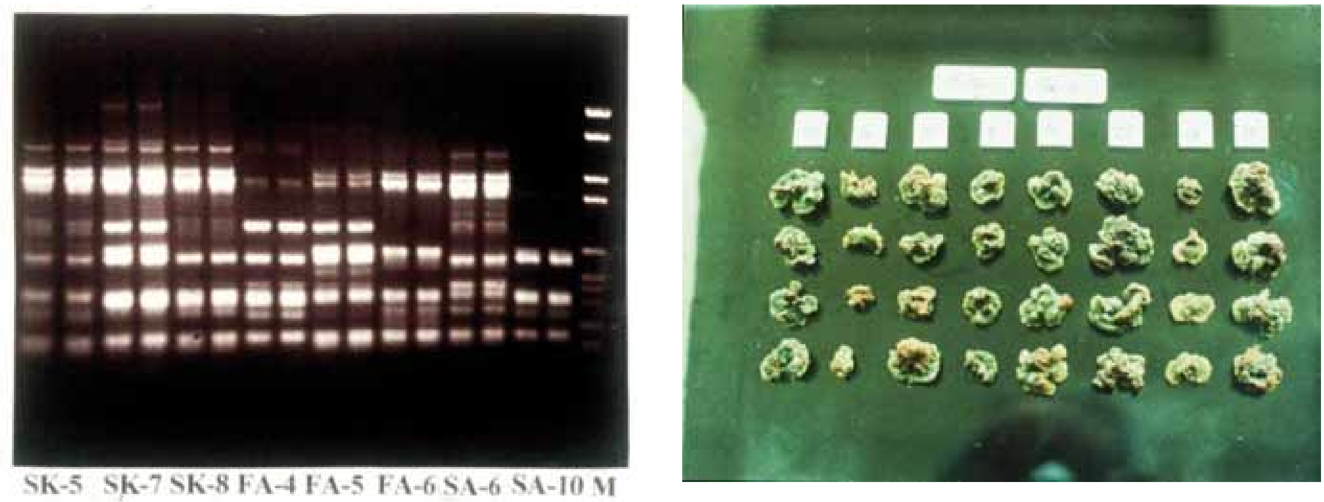


Figure 13

Genetic markers for different characters of the olive tree will have an even broader impact in the future by enabling the identification of traits of significance in overcoming possible detrimental effects of increased global warming. This goal will call for a wider genomic approach in future research to maintain the olive industry in its present large-scale locations. Future olive research will investigate various sources in order to detect the required genes. Naturally, the first source should be the large number of domesticated olive cultivars. Another, important source is the olives belonging to subspecies of *Olea europaea* that grow wild under different and even extreme environments around the world. These trees probably contain some of the genes required for future commercial olive cultivars (Fig. 14).

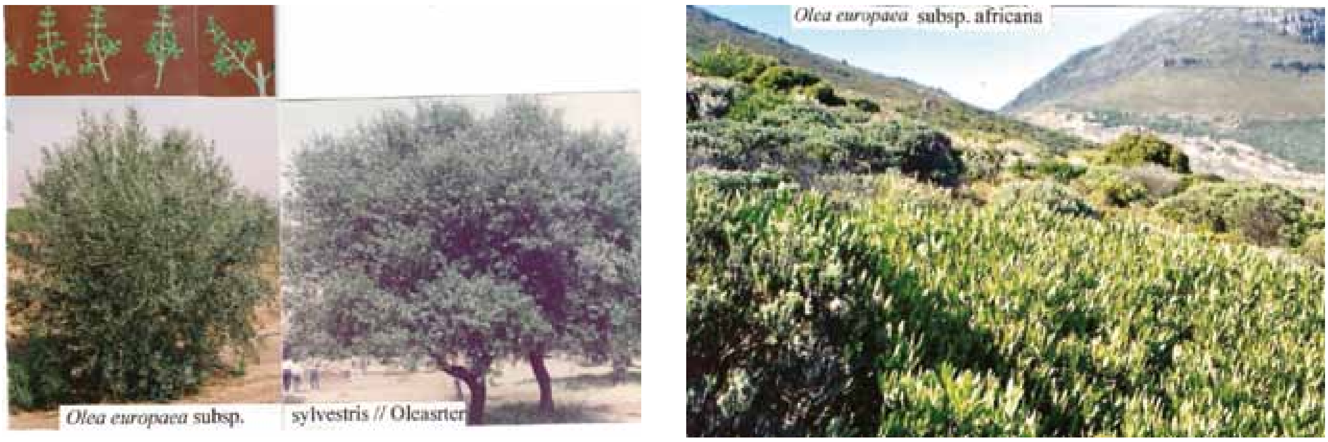


Figure 14

Furthermore, it has already been demonstrated in recent years that most of these subspecies can be crossed with the domesticated *O. europaea.* Old autochthonous trees that have survived for hundreds of years would serve as another possible gene source for specific traits, and geographically isolated, domesticated and particularly wild populations that have undergone excessive local inbreeding will be a promising additional source for some of the genes required (Fig. 15).

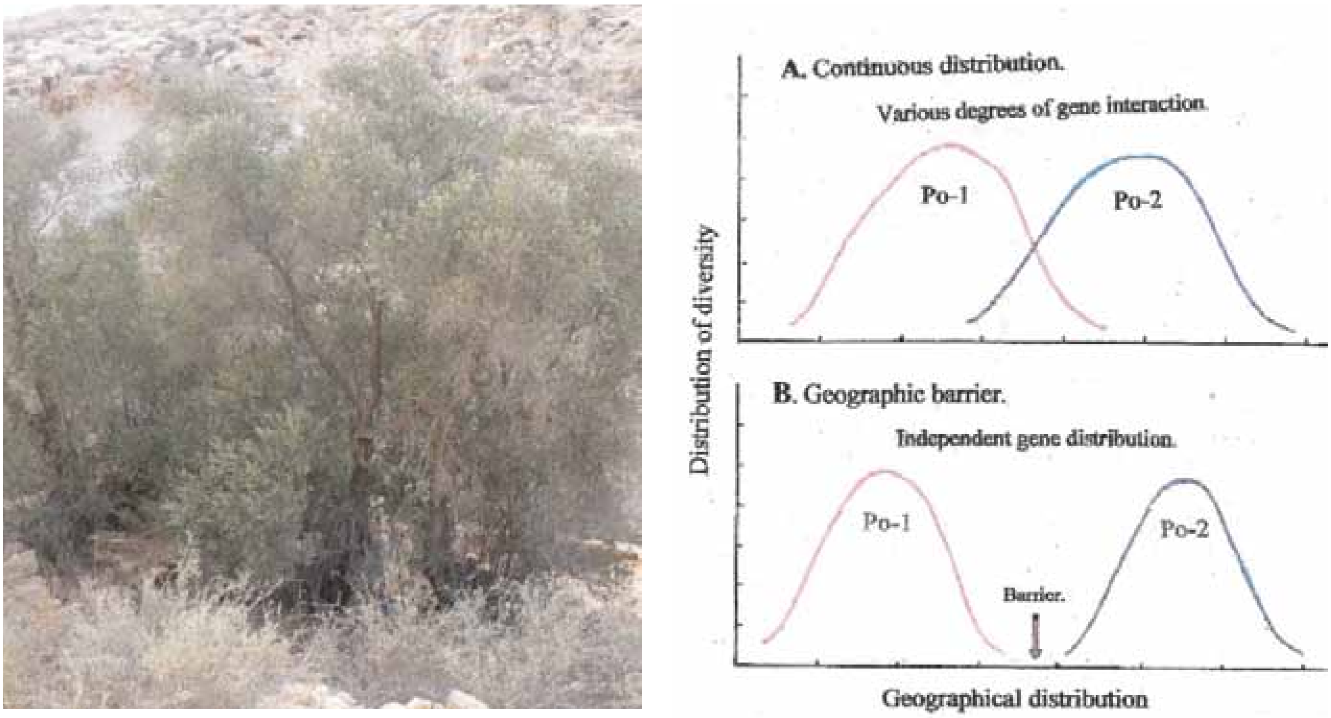


Figure 15

Although genetic engineering has not yet been accepted by the olive industry the potential response of the olive, initially reported about 40 years ago, will be the subject of some future research (Fig. 16).

Figure 16

The use and acceptance of new methodologies, particularly the possibility of specific gene transfer from one olive cultivar to another, might open up a new approach to improving and adapting olive cultivars to the goals required for the future olive industry. The importance of such methods, which do not require classic crossing, is that they have the ability to change only a specific target. Thus, they do not affect the whole genome of the genitors, in contrast with crossing which frequently causes the progeny to respond in a non-specific and often highly arbitrary manner.

Suggested additional reading

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Olive oil, a cornerstone of the Mediterranean diet

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Resumen

La Dieta Mediterránea es una de las dietas más estudiadas por su beneficio en la salud poblacional. Está demostrado que una adherencia a la Dieta Mediterránea disminuye la morbimortalidad por enfermedad cardiovascular, la incidencia de diabetes, obesidad y cáncer. Este beneficio potencial es debido al conjunto de los alimentos que la constituyen. Destaca entre ellos el aceite de oliva virgen y en especial el virgen extra que por su valor biológico y terapéutico es considerado el componente más importante en la dieta mediterránea. Su capacidad antioxidante, antiinflamatoria, antiaterogénica e hipolipemiante entre otras funciones biológicas, se debe principalmente a su composición química rica en ácido oleico, polifenoles, esteroles y tocoferoles que lo distingue de otros aceites. Esta revisión está enfocada a los efectos beneficiosos de la dieta mediterránea que en su mayor parte son atribuibles al aceite de oliva virgen, al virgen extra y a su composición.

Palabras claves

Dieta mediterránea, aceite de oliva virgen, virgen extra, componentes menores polares, antioxidantes.

Abstract

The Mediterranean diet is one of the most widely studied diets owing to its benefits for population health. Adherence to the Mediterranean diet has been demonstrated to lower cardiovascular morbidity and mortality as well as the incidence of diabetes, obesity and cancer. This potential benefit is due to its constituent foods amongst which virgin olive oil, especially extra virgin, is considered to be the most important because of its biological and health-promoting properties. Its biological functions include its antioxidant, anti-inflammatory, anti-atherogenic and lipid-lowering capacity, which is chiefly due to its chemical composition and high content of oleic acid, polyphenols, sterols and tocopherols which set it apart from other oils. This review focuses on the beneficial effects of the Mediterranean diet, the majority of which can be attributed to the composition of virgin and extra virgin olive oil.

Key words

Mediterranean diet; virgin olive oil; extra virgin olive oil; minor polar compounds; antioxidants.

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It is common knowledge that diet plays a preventive role in combating the risk of chronic diseases, especially cardiovascular diseases, which are the chief cause of morbidity and mortality in Europe. It is also known that the number of deaths from this cause can be expected to increase unless there is a change in life style.

The diet of the Mediterranean peoples first attracted the interest of scientists as early as 1938 when Leland Albaugh (1) studied the eating habits of the inhabitants of Crete, thus laying the foundation for what would later become the recommendations embodied in the Mediterranean Diet (MD) Pyramid. In 1957, Ancel Keys embarked on the *Seven Countries Study,* a longitudinal study monitoring cohorts of males between the ages of 40 and 59 from different countries (Northern and Southern Europeans and North Americans). This study was the first to report major inter-country differences in the incidence of coronary heart disease. Follow-up (5–15 years) revealed that cardiovascular mortality in southern Europe was two to three times lower than in northern Europe or the United States. These differences were associated with total and saturated fat consumption in the countries studied, as well as with the mean cholesterol of the cohorts (2-4).

The MD has been defined in several studies (5-6). It is a cultural legacy born of the geographical, historical, anthropological and cultural convergence of three continents: Africa, Asia and Europe. An amalgam of simplicity, variety, conviviality and a balmy climate led to the emergence of one of the healthiest, most complete and most balanced combinations of foods on the planet. This combination was basically made up of the foods that were produced or obtained in that geographical area such as vegetables, grains, legumes, fruit and nuts, fish, meat, eggs, milk and dairy products, olive oil (virgin and extra virgin especially) as the main source of dietary fat and moderate amounts of wine at mealtimes. Adopting a Mediterranean-style diet is an excellent way of improving the "nutritional" factor involved in the prevention of cardiovascular diseases (CVD).

Several prospective observational studies have confirmed that closer adherence to the MD is associated with a significant improvement in health stats, quality of life and longevity and a large decrease in overall mortality as well as in morbidity and mortality from CVD and other important chronic diseases. Specifically, a meta-analysis of prospective cohort studies reported that a two-point increase (on a scale of 0 to 7-9 points) in adherence to the MD was associated with a significant reduction in overall mortality (9%), CVD mortality (9%), cancer incidence or mortality (6%) and incidence of Parkinson's and Alzheimer's disease (13%) (7-14).

Cardiovascular benefits

The MD appears to be very heart-healthy; it decreases the mortality rate from coronary heart disease and protects against stroke-related mortality (10). Adherence to the MD lowers cardiovascular risk factors in persons at risk (*primary prevention)* and is associated with a reduction in cardiovascular events or mortality after the first event (*secondary prevention).*

In 2004, Katherine Esposito *et al.* reported decreases in weight, body mass index, blood sugar, blood insulin and HOMA score (homeostasis model assessment) in subjects administered a Mediterranean-style diet. The same authors also observed a decrease in plasma cholesterol, triglycerides and inflammation markers and enhanced endothelial function (15).

The *Medi-RIVAGE Study (Mediterranean Diet, Cardiovascular Risks and Gene Polymorphisms)* observed a larger decrease in body mass index, total cholesterol, low density lipoprotein (LDL) cholesterol, triglycerides, apolipoproteins A1 and B, blood insulin and HOMA score in patients with moderate CVD risk factors who were administered a Mediterranean-style diet than in those fed a low-fat diet. A reduction in plasma triglyceride levels was only observed in obese and overweight subjects in the group on the Mediterranean-style diet (16).

In 2010, the Instituto de Salud Carlos III conducted the PREDIMED Study (Spanish acronym for Primary Prevention of Cardiovascular Disease with a Mediterranean Diet) on 772 adults at cardiovascular risk. The subjects were divided into three groups: two were administered a Mediterranean-style diet (one supplemented with extra virgin olive oil (1L/week) and the other supplemented with 30 g of mixed nuts/day) and the third was placed on a low-fat diet. After three months, positive changes were noted in some variables such as blood sugar, systolic blood pressure and the cholesterol/high density lipoprotein (HDL) cholesterol ratio in the two groups administered the Mediterranean-style diets compared with the group on the low-fat diet. C-reactive protein only decreased in the group administered the Mediterranean-style diet supplemented with extra virgin olive oil (17).

The Lyon Heart Study is one of the major secondary prevention trials carried out in this sphere. It was conducted in France on 605 subjects over the age of 70 who had experienced myocardial infarction or angina and who were administered either a Mediterranean-type diet enriched with omega-3 polyunsaturated fatty acids or a low-fat diet. After 46 months' follow-up, the number of patients who had another heart attack or who died from coronary causes was 70% lower in the Mediterranean-type group than in the low-fat group (18).

Further studies document a reduction in cardiovascular risk and relative risk of heart attack recurrence when a Mediterranean-type diet is consumed as well as lower premature mortality after a first myocardial infarction (19-21). The MD lowers the risk of coronary heart disease by between 8 and 45% (22).

Benefits for diabetes and metabolic syndrome

The MD is the best diet for diabetics in that it lowers the levels of atherogenic lipoproteins, improves blood sugar control, enhances insulin sensitivity and lowers systolic and diastolic blood pressure. Overall, this leads to lower atherogenic risk and better diabetes control with all the ensuing benefits (23-26).

The MD might decrease the prevalence of metabolic syndrome and the associated vascular risk, possibly by decreasing the inflammation associated with this syndrome (15). It might also lower the concentration of pro-inflammation and pro-coagulation markers in subjects without evidence of cardiovascular disease (27).

Additionally, the MD has been associated with positive effects on the chief CVD risk factors in that it has been found to lower the incidence of hypertension, diabetes mellitus and metabolic syndrome (26, 28-31).

After controlling various confounding factors (32, 33), cross-sectional studies conducted on more than 3000 adults without evidence of CVD have reported that adherence to a Mediterranean Diet is associated with a reduction of between 39 and 50% in the probability of suffering from overweight and obesity and 59% less risk of developing abdominal obesity (32,33).

Compared with low-fat or low-carbohydrate diets, the MD causes more positive changes in blood sugar control, thus postponing the need for anti-hyperglycaemic treatment in overweight subjects recently diagnosed with type 2 diabetes. Besides lowering total body weight and enhancing sugar metabolism in the same way that a low-fat diet does, it lowers the risk of diabetes in high cardiovascular risk subjects and is associated with improved plasma antioxidant capacity (34-39).

Olive oil as a cornerstone of the Mediterranean diet

Olive oil is the distinctive feature of the MD in which it is the chief source of dietary fat. Studies have reported that olive oil, specifically virgin olive oil and best of all extra virgin olive oil, is effective in the prevention and/or reduction of hypercholesterolaemia, atherosclerosis, hypertension, cardiovascular diseases, oxidation and oxidative stress, obesity, type 2 diabetes, inflammatory processes and cancer.

In November 2004, the United States Food and Drug Administration (FDA) acknowledged the beneficial effects of olive oil on cardiovascular disease risks and recommended consuming daily about two tablespoonfuls of extra virgin olive oil (23 g).

Two basic features make olive oil stand out from other vegetable oils and explain why it is so appreciated. First, it is obtained solely from olives and can be eaten straight away (i.e. it does not need refining) when the raw material is good quality. For this reason, olive oils can only be called extra virgin when they are "oils derived solely from olives using mechanical or other physical means under conditions, and particularly thermal conditions, that do not lead to deterioration of the oil, and which have undergone no treatment other than washing, decantation, centrifugation or filtration, but excluding oils obtained by means of solvents or of re-esterification and mixtures with other oils" (41).

The biological and health-restoring worth of extra virgin olive oil is directly linked to its chemical composition. Its most important feature is that it is a true fruit juice that preserves unaltered all the components and properties of the olive fruit; it is highly nutritious and a good source of vitamins.

Composition of olive oil

Olive oil contains two clearly differentiated fractions: an oil fraction and a non-oil fraction.

The **oil fraction** accounts for 98–99% of the oil. Monounsaturated oleic acid is the main fatty acid in olive oil, accounting for 55–83% of the total. As a result, it is more heat-resistant than other oils that are rich in polyunsaturated fatty acids (PUFAs), for instance seed oils. It can therefore be used in high-temperature processes without losing its beneficial effects since it is less sensitive to oxidative deterioration because monounsaturated fatty acids (MUFAs) have only one double bond. It also contains saturated fatty acids (8-14%) such as stearic acid (4–20%) and PUFAs, the most important of which are omega-3 fatty acids like eicosapentaenoic acid and di-unsaturated fatty acids like linoleic acid (42).

Comparison of a high-MUFA diet with a high-saturate Western diet shows that the former significantly lowers LDL-cholesterol by around 10–14% and HDL-cholesterol by 2–6%. When high-MUFA diets are compared with low-fat diets (< 30% total daily kcal) and carbohydrate-rich diets, LDL-cholesterol concentrations decrease to a similar extent when compared with Western-style diets but HDL-cholesterol levels are higher in the MUFA-rich diets. In addition, when the proportion of carbohydrates remains constant and saturated fat is replaced by MUFAs, triglyceride concentrations drop (43-47).

One of the most interesting aspects of consuming diets with a high content of virgin and extra virgin olive oil is that the subjects are less prone to oxidation of LDL particles than those who consume PUFAs or carbohydrates. Sufficient data are available to assert that oxidative tendency is heightened on consuming PUFA-rich foods. In contrast, when a diet rich in virgin and extra virgin olive oil is consumed, the oleic acid is taken up by the LDLs, which become more resistant to oxidation, so preventing LDL cholesterol from causing damage. Extra virgin olive oil has a high content of natural antioxidants, which inhibits lipid oxidation, promotes vascular relaxation and prevents arteriosclerosis (48-53).

Apart their beneficial effect on lipid profile and their antioxidant properties, MUFAs also protect against thrombogenesis or blood clot formation. It has been suggested that MUFAs might reduce platelet aggregation, enhance fibrinolysis by decreasing the activity of the plasminogen activator inhibitor and reduce endothelial capacity to promote monocyte adhesion, thus generally improving endothelial function in subjects with normal and high blood lipid levels (54-58).

MUFA-enriched diets have been found to have a positive impact on glycaemic control in patients with glucose intolerance or type 2 diabetes, and these fatty acids have been observed to stimulate GLP-1 in vitro (59). It has been demonstrated that they delay gastric emptying compared with SFA-rich meals, thus preserving the reservoir function of the stomach (60, 61).

The **non-oil fraction** is the unsaponifiable or minor component fraction. It represents approximately 1–1.5% and accounts for the great biological value of extra virgin olive oil compared with seed oils. The minor components of extra virgin olive oil include sterols, tocopherols, squalene and phenolic compounds, which are behind its nutritional and organoleptic properties. It is a very heterogeneous group of substances which are present at low concentrations and give the oil its characteristic colour, taste and aroma.

These components perform very important biological functions since many of them act as natural vitamins and antioxidants and can have lipid-lowering, anti-atherogenic and anti-inflammatory effects. They also protect the oil from autoxidation and rancidity.

Minor component content can be affected during oil refining processes because many of them are water-soluble and temperature-sensitive and are easily lost or destroyed (62).

Amongst the hydrocarbons, squalene is very significant quantity-wise. It too exerts an effect on cholesterol and terpene alcohols (cycloartenol is particularly interesting because it promotes faecal excretion of cholesterol via increased bile acid excretion).

Sterols

Sterols such as campesterol, stigmasterol and β-sitosterol (present in the largest percentage) have been detected in extra virgin olive oil. Owing to their similar structure to cholesterol, they have a significant effect on cholesterol regulation by displacing the cholesterol from the micelles in the gut, thus lowering dietary cholesterol absorption. As a result, LDL cholesterol is lower (63).

Polyphenols

Polyphenols are natural antioxidants in the polar fraction of virgin olive oils. There is evidence that the autoxidative stability of these oils is due in particular to their high polyphenol content, particularly of ortho-diphenols. Lignans (acetoxy-pinoresinol and pinoresinol) and secoiridoids are the chief principal components in the phenolic fractions of extra virgin olive oil although simpler phenols such as hydroxytyrosol, tyrosol and oleuropein (64) also have antioxidant capacity.

Phenolic compounds also contribute to the astringency and bitter taste of extra virgin olive oils. The heart-healthy properties of these oils are currently attributed to these compounds, especially hydroxytyrosol and also oleuropein, both of which are powerful antioxidants (65).

Phenolic compounds exert an antioxidant effect by protecting LDLs from oxidation and breaking peroxidation chain reactions. They inhibit the enzymes involved in inflammatory processes as well as procarcinogen metabolism.

In the EUROLIVE study, initiated in 1998 by the Institut Hospital del Mar d'Investigación Mèdique (IMIM) volunteers were administered similar doses of olive oils with differing polyphenol contents (low, medium and high) and even at lower concentrations than those consumed daily in a Mediterranean-style diet (25 ml/day) for three-week periods. HDL cholesterol recorded a linear increase in relation to polyphenol dose. Triglyceride levels decreased in all cases on administering virgin olive oil and not solely on administering oil with a high phenolic content. Total cholesterol/HDL cholesterol ratio decreased in direct proportion to the polyphenol content of the oils. Lastly, the oxidative stress markers (LDL oxidation) also decreased with increasing polyphenol content in the virgin olive oil. This study considers polyphenols to play a part in the cardiovascular risk reduction associated with consumption of virgin olive oil, owing to their antioxidant effect on lipid profile. Hence, virgin olive oil is the oil that affords the best protection from oxidative damage (66).

In the Virgin Olive Oil Study (VOLOS) conducted in Italy, Visioli *et al* (77) observed that the administration of 40 ml/day of phenolic-rich virgin olive oil led to a decrease in plasma TXB_2 levels after 7 weeks compared with an oil with a lower content of these components (67).

A recent randomised cross-clinical trial conducted on a small group of healthy patients has revealed that a high-extra virgin olive oil MD not only improves endothelial function and lowers systemic inflammation but also improves the number of endothelial progenitor cells (68, 69).

It has been observed that consumption of virgin olive oil in general lowers DNA oxidation levels, which are considered a possible risk factor in the development of cancer (70, 71).

Several research projects have highlighted the beneficial effect of extra virgin olive oil in reducing the risk factors of, and preventing, breast, bowel and rectal cancer (74, 75). Evidence-based epidemiological studies assert that cancer incidence in southern European countries where there is a high consumption of virgin and extra virgin olive oil is comparably lower than in northern European countries (76).

The effect of oil polyphenols (natural antioxidants) on cancer cell lines has been analysed in breast cancer research. It has been observed that polyphenols exert a selective anti-tumour effect on oncogen HER2, which is responsible for the development of cancer (77).

To conclude, the MD and virgin olive oil, particularly extra virgin, are very beneficial for health in that they lower chronic disease incidence by controlling certain risk factors and they raise life expectancy, as has been demonstrated in intervention and epidemiological studies. This is why it is so necessary to promote their consumption and advise against foods with a high energy density (saturated fats and sugars) and cholesterol and salt content which, coupled with a sedentary lifestyle, impact on population health by increasing chronic diseases.

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Virgin olive oil and sports

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Resumen

Múltiples estudios [1,2,3,4,] realizados en los últimos años han ilustrado los efectos del ejercicio físico intenso sobre marcadores biológicos (hematológicos, celulares, bioquímicos y hormonales). Aunque la química del oxígeno es necesaria para la vida y positiva para los sistemas biológicos del cuerpo humano, algunas moléculas generadas por el metabolismo del oxígeno tras un ejercicio físico intenso se encuentran implicadas en el daño celular, el envejecimiento y las enfermedades cardiovasculares. Estas moléculas son los “radicales libres” (RL), y el proceso de su formación se denomina “stress oxidativo”. Para contrarrestar los daños provocados por este último, es esencial la asunción de alimentos ricos en sustancias capaces compensar el desequilibrio producido: son los antioxidantes. Entre ellos, un papel predominante está representado por la vitamina E, cuyas potentes propiedades antioxidantes y poder en la prevención frente al daño celular, el envejecimiento y múltiples enfermedades han sido objeto de creciente interés en los últimos años. Los aceites vegetales, y en concreto el aceite de oliva virgen extra, proporcionan una de las fuentes principales de aporte de vitamina E a través de la dieta. Este trabajo es una revisión de estos aspectos.

Palabras clave

Ejercicio físico intenso. Radicales libres. Antioxidantes. Vitamina E. Aceite de oliva virgen extra.

Abstract

The effects of strenuous physical exercise on biological markers (haematological, cellular, biochemical and hormonal) have been reported in several papers[1,2,3,4,5] in recent years. Although oxygen chemistry is necessary for life

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and positive for the biological systems in the human body, certain substances produced by oxygen metabolism after strenuous exercise are directly implicated in cellular damage, ageing and cardiovascular diseases. These substances are called free radicals and the biochemical process involved in their formation is termed oxidative stress. To counteract damage induced by oxidative stress, it is essential to consume foods that are rich in antioxidants, which are capable of offsetting the resultant imbalance. The powerful antioxidant properties of vitamin E and the predominant role it plays in preventing cellular damage, ageing and several diseases has attracted growing interest in recent years. Vegetable oils, and specifically extra virgin olive oil, are one of the main dietary sources of vitamin E. This paper provides a review of these aspects.

Key words

Strenuous exercise; free radicals; antioxidants; Vitamin E; extra virgin olive oil.

Physical exercise: metabolic and physiological changes

The practice of sport is one of the major social changes of the 20th century. The clear link between sedentarism and cardiovascular and metabolic diseases (hypertension, ischaemic heart disease, cerebrovascular accidents in the first case and diabetes, dyslipidaemia, hyperuricaemia in the second) and the prevention of these and other diseases (obesity, osteoporosis) in people who take regular physical exercise has led national health authorities to invest large amounts of money in promoting healthy lifestyles in which physical exercise is one of the fundamental pillars. Many studies[6,7] concur that when adapted to age and physical fitness, physical exercise and sports can be so beneficial for health that they are capable on their own of exerting a decisive influence on homeostasis in the body.

Regular physical exercise at moderate intensity leads to metabolic and physiological changes, the most significant of which occur at tissue and cardiocirculatory/pulmonary level. At tissue level, it helps to increase energy production and improve the elimination of metabolic waste; at cardiocirculatory and pulmonary level, it increases heart and ventricular cavity size, lowers basal or resting heart rate and blood pressure and enhances pulmonary ventilation and efficiency. It also modifies body composition, reduces cholesterol levels and produces changes in heat acclimatisation.

Besides these metabolic and physiological changes, physical exercise increases energy and muscular oxygen requirements. If exercise is vigorous, cell metabolism produces more molecules, some of which – free radicals – may damage the tissue itself.

In point of fact, although regular moderate physical exercise has proved to have beneficial effects on the body, vigorous physical activity induces metabolic and physiological changes resulting in the production of a series of very harmful molecules generated by oxygen metabolism that cause oxidative stress.

This stress can be measured by the increase in lipid peroxidation markers and is indicative of cell damage. To remedy this damage, athletes must consume a diet containing nutrients which cover their quantitative and qualitative requirements. Fat is their fundamental source of energy. Owing to its characteristic monounsaturated fatty acid composition and its high content of vitamin E, polyphenols and antioxidants, olive oil, and specifically extra virgin olive oil, is the optimal dietary source of fat for anyone who practises sports in general, especially at top-flight, demanding levels.

This article will show how monounsaturated fats – one of which is extra virgin olive oil, which stands out because of its distinctive composition – are one of the most suitable energy sources to meet the energy requirements generated by physical exercise.

Olive oil is extracted from the olive, a single-stone ovoid drupe. The olive fruit consists of a woody stone or endocarp (15–23% of fruit weight) enclosing a seed or kernel, in addition to the flesh or mesocarp (70–80%), and an outer skin or exocarp (2–2.5%). Fruit composition at harvest should be made up of approximately 40–55% water, 18–32% oil, 14–22% stone and 1–3% seed or kernel; the remaining 8–10% should be skin and the rest of the flesh. Extra virgin olive oil has a very characteristic fatty acid composition including oleic acid (55–83%), linoleic acid (10%) and palmitic acid (13%)[9]. It is also composed of sugars, proteins, pectins, oleuropein, phenolics, phytosterols, inorganic compounds, vitamins and other substances, which vary in proportion according to factors such as tree age, type of cultivation, climate, fruit ripeness and variety.

Energy requirements and exercise

Human beings satisfy their energy requirements via the diet in order to cover their vital needs. The ***basal metabolic rate*** is the energy needed to maintain vital *functions* at rest (respiration, digestion, blood circulation, body temperature, etc.) while ***activity energy expenditure*** is the energy required to perform any other activity. When the two are added together, they give ***total energy expenditure***. Quantitatively speaking, basal metabolism varies little in healthy people through life according to gender and age whereas energy expenditure can differ considerably depending on physical activity at any given time. Basal metabolism in women (healthy women weighing 60 kg) ranges from 1,460 kcal/day when they are in their twenties to 1,170 kcal/day when they are over the age of 65; in men (healthy men weighing 72 kg) it ranges between 1,820 kcal/day and 1,410 kcal/day, respectively. In contrast, energy requirements to offset calorie expenditure vary a lot according to the type of exercise: 3.7–4.2 kcal/minute for yoga (240 kcal/hr), 10–12 kcal/min for running (660 kcal/hr), and 15–17 kcal/min for karate (900 kcal/hr)

Hence, physical exercise leads to increased energy demand which has to be covered via the **diet.** There are major differences between amateur and elite athletes both in terms of energy expenditure and diet. Amateur athletes merely need a balanced diet in which calorie intake is adjusted to expenditure; elite athletes need to supplement their normal diet not only quantity-wise but also quality-wise by consuming substances that help them to recover effectively and efficiently from energy expenditure (supplements) and which prevent the tissue damage (antioxidants) caused by the oxidative stress generated by physical exertion.

Energy sources

The nutrients that make up the food in our diet are the source of energy for our body and more particularly for our skeletal muscle which ultimately powers physical activity. The most important ones are **fats** and **carbohydrates.** Once eaten and digested, these undergo biochemical changes which produce energy-containing molecules that are later used by the cells.

Skeletal muscle obtains the necessary energy to power muscle contraction through three fundamental pathways: the phosphagen system, anaerobic glycolysis and the oxidative system[10]. Although none of these systems participates exclusively throughout exercise, the muscle will preferably obtain energy from one or the other depending on the activity (power/resistance) and its intensity and duration.

Fats, a fundamental source of energy

Lipids are a fundamental component of the human diet and one of the major energy sources for the development of all human functions. They are made up of a very varied set of natural molecules including fats, waxes, sterols, liposoluble vitamins, phospholipids, etc. Their most important biological function is the long-term storage of energy in the tissues in the form of triacylglycerols; they also play a leading part in cell membrane formation.

When stored in the body, dietary lipids act as an energy store cupboard and become particularly important during exercise the longer it lasts. When consumed, the fatty acids are deposited and stored in the adipose tissue cells (adipocytes), circulating lipoproteins and muscle cell triacylglycerols for use as required. As the duration of physical activity increases, so too do blood supply to the adipose tissue and catecholamine and growth hormone-induced lipolysis, which helps to mobilise fatty acid reserves and energy sources. The subsequent reactions in the body produce adenosine triphosphate (ATP) energy molecules; the energy yield of each substance differs, not only between the basic nutrients (amino acids, carbohydrates, lipids) but also between each compound in each group.

The energy yield from complete fatty acid oxidation is 9 kcal/g and 4 kcal/g from carbohydrates and proteins. Comparatively speaking, 1 g of nearly anhydrous fat stores six times as much energy as 1 g of hydrated glycogen. A typical 70-kg male has fuel reserves of 100,000 kcal in triacylglycerols (fats), 250,000 kcal in proteins, 600 kcal in glycogen and 40 kcal in glucose. This explains why the glycogen and glucose stores would provide only enough energy to sustain biological functions for 24 hours and the necessary energy to cover requirements in the first few minutes of physical activity because they would be used up straight away. Conversely, lipids would enable survival for days in the event of lack of food or would provide energy for prolonged exercise.

Saturated and monounsaturated fatty acids: characteristics and effects on health

Fatty acids are constructed from carbon, hydrogen and oxygen arranged in a carbon chain with a carboxylic group at one end. Depending on whether or not there are double bonds between the carbon molecules, they are classified as saturated (no double bond), monounsaturated (one double bond) or polyunsaturated (more than one double bond). Linoleic and α-linolenic acid (with two and three double bonds, respectively) are essential fatty acids (EFAs) for humans which cannot be synthesised by the body because mammals lack the necessary enzymes to insert double bonds at carbon atoms beyond C-9. Hence, EFAs can and must only be obtained through the diet; they serve as the basis for synthesising the rest of the more unsaturated fatty acids and their metabolic products needed by the body. Longer-chain, more unsaturated fatty acids undergo enzymatic metabolism to produce a large variety of products known as eicosanoids which play a central role in cell physiology by controlling vascular smooth muscle inflammation and tone (leukotrienes), antagonising platelet aggregation (prostacyclins) and regulating immune response (prostanoids). For this reason, EFAs or unsaturated fatty acids are important in the prevention of cardiovascular diseases.

Cereals, nuts, oily fish and virgin and extra virgin olive oil are the main source of EFAs. A diet rich in these products is therefore clearly a "fountain of health" to keep closely in mind when trying to keep and stay fit and healthy.

The oxygen paradox: free radicals

As early as the end of the 19th century it was known that oxygen, so essential for life, could also be harmful and cause cell damage through the formation of certain oxygen-associated substances – free radicals (FRs) – in specific circumstances. This was later dubbed the "oxygen paradox".

FRs are molecules or fragments of molecules (atom or cluster of atoms) with one or more unpaired electrons in their outermost shell (Holmberg 1984). FR formation is quite common in the body because FRs are constantly generated from different molecules in physiological conditions; however, oxygen-generated FRs wield the most influence in disease processes such as cancer. Oxygen toxicity is not due to the oxygen molecule itself but to its highly reactive metabolic products: anion superoxide (O^-_{2}), hydrogen peroxide (H_2O_2) and the hydroxyl radical (OH^-)[3].

When a sport is practised, oxygen demand increases in proportion to the intensity of the exercise. Consequently, the intermediate metabolites of energy metabolism also increase. Oxygen consumption may be 10–15 times higher, thus generating larger quantities of oxygen-associated FRs[11]. Because these molecules are unstable, they have a great ability to produce chain reactions with adjacent molecules thus generating new FRs, which do so in turn with other FRs. These molecules react with the components in the body and may even alter its function. For instance, if the reaction occurs with nucleic acids, it could cause damage to genetic material and pave the way for certain neoplasmic diseases such as bowel cancer; if it occurs with cell wall proteins (protein oxidation) and lipids (lipid peroxidation) it could led to cell ageing and even premature cell death. Several authors[12,13] have documented oxidative stress-induced cell damage after gruelling exercise.

When exercise is practised regularly, the body adapts to increase the distribution and activity of other substances that prevent cell damage by blocking the FRs; when exercise is vigorous, these systems are overwhelmed and cell damage occurs. This is when antioxidants step into the limelight. They are the body's induced (exogenous) or intrinsic (endogenous) response to cope with FR damage.

Endogenous or exogenous antioxidants; the importance of diet

The body has a system that removes FRs and so prevents the damage they cause. In this system antioxidants scavenge the FRs to make them stable and no longer harmful.

Antioxidants are endogenous when they are produced by the cell itself (glutathione, coenzyme Q, thioctic acid, superoxide dismutases, catalase and the glutathione peroxidase system) and exogenous when intake is via the diet or supplements (vitamins E and C, carotenes and flavonoids)[14,15]. The glutathione peroxidase system is considered to be pivotal in the antioxidant defence of the body; the tocopherols (vitamin E) in the cell membrane prevent damage to the cell wall by reacting with the FRs. Although each antioxidant has a greater affinity with a specific FR, they can perform their function with several types of FR and affect the processes that generate them.

Virgin and extra virgin olive oil contain a large amount of natural antioxidants, including polyphenols and alpha-tocopherols. Polyphenols are naturally occurring chemical substances found in some plants and foods; olive oil is the only fat to contain these antioxidants. Alpha-tocopherols are related to vitamin E, one of the micronutrients fundamental to human health.

Vitamin E: a powerful antioxidant

In 1925, the letter "E" was assigned to designate vitamin status to the factor discovered earlier by Evans, "E" being the next serial alphabetical designation after the preceding discovery of vitamin D by Elmer McCollum in 1922. Years later, Emerson managed to isolate and purify this E factor and named it *tocopherol* [from the Greek for *tokos* (childbirth, due to the anti-abortive properties of this vitamin observed in mice), *pherein* (to carry, bear) and "-ol", indicating an alcohol[16]]. The term vitamin E is used to designate a group of eight natural species of tocopherols and tocotrienols (α, β, γ and δ); it is one of the liposoluble vitamins. Alpha-tocopherol is the only form to have vitamin activity for humans. It is an essential compound, i.e. it is not synthesised by the body and is therefore obtained solely through the diet, which is of particular relevance to the subject matter of this article, namely olive oil and particularly extra virgin olive oil. Alpha-tocopherol absorption in humans requires the presence of bile and certain lipolytic pancreatic and intestinal mucosa enzymes. Its most important natural sources are vegetable oils (olive oil, virgin and extra virgin), whole cereals, nuts, meat, etc. No studies have determined the exact daily vitamin E requirements of humans because they vary according to age, sex, health, etc. Adverse effects of excessive vitamin E consumption in the form of supplements have been reported (haemorrhagic toxicity) but none has been reported for normal dietary consumption. The risk of uncontrolled intake of vitamin supplements is due to the fact that because it is liposoluble, vitamin E can be stored in the adipose tissue and liver. Recent research ([17,18,19]) has shown that the intake of amounts above the recommended levels might lower cardiovascular risk, but consistent results are still lacking on the appropriate amount and the target population.

Currently, findings are conclusive about the essential role of vitamin E in normal cell functioning at rest and during exercise; Davies *et al.* (1982) reported increased FRs in the tissue of persons with vitamin E deficiency similar to the level in health persons while exercising. There are several theories about the function of vitamin E in the body. The most widely accepted one is that since it is a lipophilic antioxidant it is located in the cell membrane where it protects the constituent lipids from FR peroxidation by neutralising the superoxide anion, capturing the hydroxyl FRs and superoxide anions and breaking the chain reaction, generally by donating a hydrogen atom to the peroxyl radical, thus generating stable complexes.

Benefits of virgin and extra virgin olive oil

Extra virgin olive oil has a very distinctive fatty acid composition (55–83% oleic acid, 10% linoleic acid and 13% palmitic acid) although it varies depending on factors such as tree age, soil type, climate, etc. Oleic acid (9-octadecenoic acid) has 18 carbon atoms and one double bond while linoleic acid (9,12-octadecenoic acid) has the same number of carbon atoms but two double bonds. The ratio of unsaturated to saturated fatty acids in extra virgin olive oil is 4.6, which determines its beneficial profile for cholesterol-related cardiovascular diseases. The unsaponifiable fraction of extra virgin olive oil, i.e. the part not made up of fatty acids representing 2% of oil weight, contains α-tocopherol, the most active form of vitamin E. In normal conditions of production and handling, α-tocopherol is not affected; conversely, if processing conditions are not correct or the oil is heated, it is destroyed. A daily intake of 25 g of extra virgin olive oil provides 25% of the recommended daily allowance of vitamin E for men, and 62% of that for women (Mataix, 2001). Extra virgin olive oil is considered to have 12 mg/100 g of vitamin E[20]. In optimal conditions, its absorption in the first section of the small bowel is relatively low – around 20–40% of intake – due to the lipases and bile salts.

According to scientific evidence [21,22,23] the antioxidants in olive fruits decrease as fruit ripening progresses. As a result, there is a tendency to harvest the olives early in order to ensure higher antioxidant content. Likewise, besides altering the composition, taste and nutritional and biological value of the oil, handling and refining may also lead to considerable losses in vitamin E content.

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Virgin olive oil in the fight against ageing

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Resumen

Los múltiples beneficios que el consumo del aceite de oliva virgen proporciona a la salud también incluyen un enlentecimiento del proceso de envejecimiento. Entre los valores nutricionales que contiene el aceite de oliva virgen destacan los que actúan sobre el aparato circulatorio al prevenir la aterosclerosis y las afecciones cardiovasculares. Una dieta rica en aceite de oliva virgen reduce el colesterol total y el colesterol LDL, evitando la oxidación de estas lipoproteínas, y aumentando el HDL.

Gracias a sus componentes, el aceite de oliva virgen actúa asimismo sobre el sistema endocrinológico al mejorar el control de glucosa en la sangre y aumentar la sensibilidad a la insulina.

A nivel del sistema nervioso, el consumo de aceite de oliva virgen evita la pérdida de memoria y la debilidad mental, manteniendo las funciones cognitivas en sujetos sanos de edad avanzada lo que parece relacionado con el papel que desempeña el ácido oleico en el mantenimiento de la integridad estructural de las membranas neuronales.

Sobre el tejido óseo estimula el crecimiento y favorece la absorción del calcio y la mineralización.

En la calidad de la piel ejerce un efecto protector y tónico de la epidermis por el efecto antioxidante de la vitamina E (efecto antienvejecimiento).

Palabras clave

Aceite de oliva virgen, polifenoles, anti oxidación, inflamación, envejecimiento, radicales libres.

Abstract

One of the numerous health benefits of virgin olive oil is that it slows down ageing. Among its nutritional assets, it helps to prevent atherosclerosis and cardiovascular diseases through its effect on the circulatory system. A diet rich in virgin olive oil lowers total and LDL cholesterol, prevents LDL oxidation and raises HDL cholesterol.

In addition, thanks to its composition, virgin olive oil affects the endocrine system by improving blood glucose control and enhancing insulin sensitivity.

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It acts on the nervous system by preventing memory loss and mental weakness and maintaining cognitive function in healthy, elderly subjects. This appears to be related to the role played by oleic acid in maintaining the structural integrity of the neuronal membranes.

Virgin olive oil stimulates bone tissue growth and encourages calcium absorption and mineralisation.

It also protects and tones the skin due to the antioxidant, anti-ageing effect of vitamin E.

Key words

Virgin olive oil; polyphenols; antioxidation; inflammation; ageing; free radicals.

Ageing: oxidation and free radicals

Ageing is a dynamic process. It is not due merely to the passing of the years but also to many different causes which are not solely genetic in nature, such as cell response capacity to external injury to cellular respiration. Tissue oxidation, which involves chemical reactions triggered by oxygen-reactive species including oxygen ions, peroxides and free radicals, is one of the factors in the ageing process that has been studied most extensively.

Free radicals are highly unstable atoms or molecules with one unpaired electron. Oxygen-driven reactions occur constantly in the human body and lead to the formation of free radicals.

The human body is equipped with a complex network of antioxidant metabolites and enzymes to prevent potential oxidative damage to cells; however, in the long term, changes in the nucleic acids, enzymes and polyunsaturated fatty acids that make up the lipids in the cell membrane produce ageing and cell death.

The human body is made up of molecules, clusters of paired atoms; this characteristic is what lends stability to molecules. The constituents of cell membrane include fatty acids, some of which are not very stable. They have a greater tendency to oxidise and are sensitive to the action of free radicals. Through its effect on the membrane lipids, oxidation leads to cell destruction. Free radicals affect any of the cells or tissue in the body and give rise to varied, general effects.

The structures that are most sensitive to these effects are the nervous tissue and brain whose system contains a huge number of polyunsaturated fatty acids; the cardiovascular system because oxidation of "bad" LDL cholesterol is involved in the onset of atherosclerosis (LDL oxidation chiefly entails the oxidation of fatty acids that are unsaturated and esterified with cholesterol molecules); bone and conjunctive tissue because oxidation of collagen and elastin leads to wear and tear of joints and loss of bone mass; and the skin, the elasticity of which depends partially on collagen and elastin (deterioration of these proteins causes skin thinning and the appearance of wrinkles).

The most effective means of combating free radicals is to apply antioxidants and to protect the mechanisms that regulate the oxidative stress which can interrupt the chain of oxidation reactions. As long as there are sufficient quantities of antioxidants and oxidative stress defence mechanisms work properly, free radical-induced cell deterioration can be slowed down. Virgin olive oil, particularly extra virgin olive oil, contains numberless antioxidant compounds capable of exerting a strong protective effect against ageing. Notable examples are beta carotenes, which have antioxidant vitamin A activity, vitamin E and other phenolic compounds (1).

Virgin and extra virgin olive oil are rich in oleic acid, an omega-9 monounsaturated fatty acid which protects the blood vessels by reducing the risk of cardiovascular disease; it also helps to regulate lipid metabolism. In addition, both virgin and extra virgin olive oil are a source of more than 30 phenolic compounds, chiefly oleuropein, hydroxytyrosol and tyrosol, all of which display antioxidant activity and are therefore capable of eliminating free radicals. In actual fact, hydroxytyrosol is one of the most effective and most powerful antioxidants known. Vissers *et al* (2) analysed the effects of the phenolic compounds in virgin olive oil on cell oxidation biomarkers in humans and animal models and estimated that 50 g or three tablespoonfuls of virgin olive oil per day provides 2 mg of hydroxytyrosol.

The antioxidant effects of virgin olive oil are due to its content of oleic acid and the presence of the minor components mentioned (3)

Anti-Inflammatory Activity

The polyphenols and phenolic compounds in virgin olive oil also have anti-inflammatory properties. Ten milligrams of virgin olive oil contain almost 5 mg of polyphenols (4). Hydroxytyrosol and oleocanthal inhibit the production of cyclooxygenase, an enzyme responsible for the production of prostaglandins, while oleuropein is capable of blocking the oxidation of the low-density lipoproteins to which cholesterol is bound.

Some of the micronutrients in virgin olive oil are believed to modulate various genes, for instance by repressing the transcription of the genes that encode proteins directly associated with inflammatory response. In a paper published in 2010 Camargo *et al.* (5) reported that consumption of virgin olive oil prevented the action of genes involved in the onset of dyslipidaemia and type II diabetes and decreased tissue inflammation. The same authors recently published research reporting that consumption of virgin olive oil reduces the risk of atherosclerosis and enhances the antioxidant profile of vascular endothelium (6). When compared with other fats and oils, virgin olive oil significantly lowers some inflammation markers and increases the plasma levels of apolipoprotein A-1, which prevents the cell changes associated with ageing (7) by acting on the vascular endothelium (internal wall of the blood vessels).

One well known characteristic of ageing is a degree of inflammation associated with deterioration and disabilities in the elderly (8) that affect not only the nervous system, blood vessels or skeleton tissue but also the immune system (9).

Vitamin E, which is found in virgin olive oil, appears to exert an effect at cell level in the cytoplasm and the cell nucleus by modifying the expression of the genes responsible for inflammatory response and immune response (10).

Effect on the vascular system associated with ageing; atherosclerosis

Research has documented that a diet enriched with virgin olive oil diminishes blood platelet sensitivity to aggregation (11) besides lowering plasma levels of coagulation factors such as A2 thromboxane and the Von Willebrand factor (vWF). This factor is a blood glycoprotein involved in initial haemostasis. Together with fibronectin, its function is to mediate the stable adherence of platelets to the surface of damaged endothelium. It also protects coagulation factor VIII.

Regular intake of virgin olive oil can increase fibrinolytic activity, so reducing the risk of thrombosis.

In addition, studies comparing people over the age of 65 who regularly consume virgin olive oil as their chief dietary source of fat with non-consumers have demonstrated that the risk of stroke is up to 40% less in the first group than in the second (12). The PREDIMED trial (13) conducted in a large, cardiovascular-risk cohort has demonstrated that both systolic and diastolic blood pressure decreased in patients assigned a diet supplemented with virgin olive oil for one year. This effect was observed to be due to increased nitric acid and increased urinary excretion of dietary polyphenols. Nitric acid relaxes the artery wall and is decisive in regulating blood pressure. Polyphenols are believed to protect the cardiovascular system not only by improving blood cholesterol levels and preventing LDL cholesterol oxidation but also by relaxing the artery wall and reducing vascular pressure. Other results obtained in the PREDIMED trial document a decrease in overall mortality and cardiovascular-related mortality (14). Every 10 g of virgin olive oil consumed per day led to a decrease of 7% in total mortality and 10% in cardiovascular mortality.

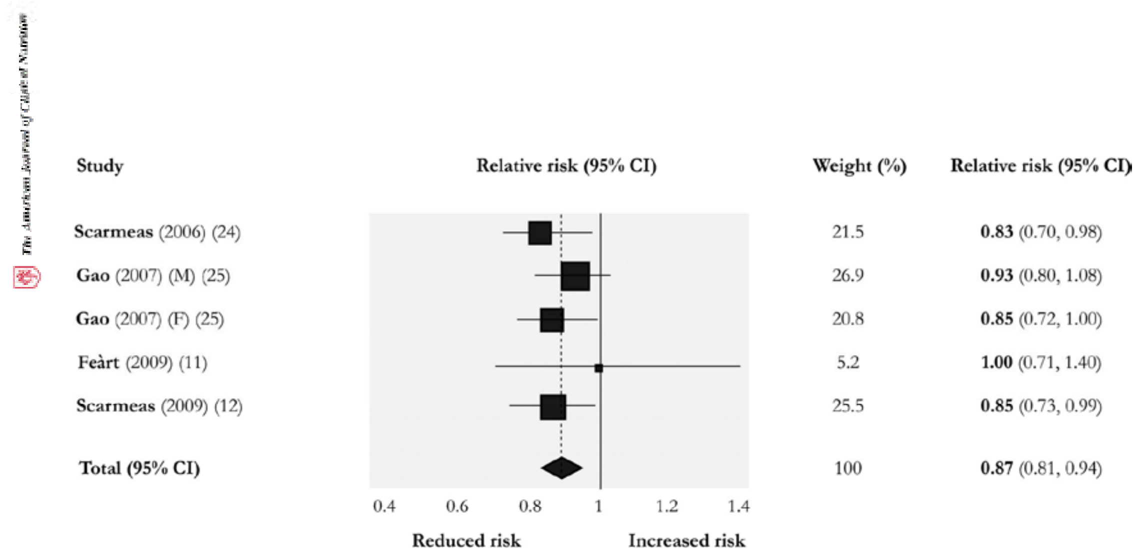
Effects of virgin olive oil on dementia and Alzheimer's disease

Recent research (15) shows that virgin olive oil protects against age-related cell deterioration and reduces skin ageing as well as the risk of osteoporosis and even of Alzheimer's disease.

Oleocanthal (a component exclusive to extra virgin olive oil that is structurally related to oleuropein and probably responsible for some of its organoleptic characteristics) is capable of preventing beta-amyloid accumulation in the brain. Additionally, it enhances beta-amyloid clearance because it increases the activity of the enzymes responsible for its degradation (15) while oleuropein may interfere with beta-amyloid-mediated toxicity. The PREDIMED trial also reported better cognitive, learning and memory capacity and lower incidence of dementia in the subjects on the virgin olive oil diet.

In a review published in 2010 (16) Sofi *et al* reported an inverse relationship between the consumption of a diet in which virgin olive oil is the main dietary fat and the risk of neurodegenerative diseases (Figure 1). The polyphenols and oleic acid in virgin olive oil affect the sugars (glucose) in the cells that are related with hormonal and neurological transmitter activity. Neurotransmitters are the chemicals responsible for signalling in the nervous system. The ones most affected by oxidation are gamma aminobutyric acid (GABA), which is connected with memory and learning capacity; serotonin which is the precursor of melatonin; and adrenaline, noradrenaline, acetylcholine and dopamine, the shortage of which causes Parkinson's disease (17).

Forest plot of the association between a 2-point increase of adherence score to the Mediterranean diet and the risk of incidence of neurodegenerative diseases.



Francesco Sofi et al. Am J Clin Nutr 2010;92:1189-1196

Furthermore, a degree of inflammation of the central nervous system (CNS) associated with mycroglial activation and the production of cytokines such as tumour necrosis factor alpha (TNFα) and interleukin-6 (IL-6) is related to the onset of neuropsychiatric symptoms in the elderly (18). Research by Berr (19) reported lower prevalence of cognitive decline and adequate maintenance of visual memory in subjects who consumed large amounts of virgin olive oil, compared with those who never consumed it. These observations are an example of the role of virgin olive oil as one of the chief dietary factors in the prevention of vascular dementia.

Effects of olive oil on the skeletal muscle system

Another protective aspect of virgin olive oil is its ability to reduce the risk of osteoporosis. It prevents bone demineralisation by enhancing bone calcium uptake via osteocalcin (20).

Virgin olive oil also improves skeletal muscle function associated with age-related oxidative stress (21). Hydroxytyrosol protects the functional capacity of the muscles, which suffer from oxidative stress-mediated decline with age. Thanks to its high oleic acid content, virgin olive oil prevents bone calcium loss during ageing. Research conducted by Laval-Jeantet (22) as far back as 1976 documented a positive correlation between virgin olive oil and bone mineralisation. This same result was reported in later experimental research (23) as well as in observational studies (24) in which two-year monitoring of patients administered a virgin olive oil-rich diet reported a higher serum concentration of osteocalcin (a hormone produced in bone cells which helps bone calcium uptake) and a higher concentration of procollagen, a precursor of collagen, which has a protective effect on bone mineral loss and osteoporosis. Moreover, monounsaturated oleic acid helps cell mitochondria to maintain adequate bone replacement by reducing age-related bone loss (25).

Protective role of olive oil in skin sgeing

Through the centuries, olive oil has been used empirically in the manufacture of cosmetics. Virgin olive oil is a major source of vitamin E, which is necessary to maintain skin elasticity. For this reason, it is also used to improve and maintain hair elasticity by reducing the risk of breakage and dryness.

Skin ageing is due to person-specific factors as well as external factors, particularly ultraviolet solar radiation, which causes the appearance of skin blemishes and wrinkles and loss of skin elasticity. With ageing, skin enzymatic activity decreases and is modified. Collagen, the main protein in the dermis and cartilage, is the chief supporting fibre of the skin and its structure is altered by ageing. As a result, the supportive skin tissue and cohesion between the dermis and the epidermis is weakened and the skin becomes less toned and firm.

Free radicals contribute to ageing because they take their missing electron from the connective tissue cells and especially from collagen. During ageing, this molecule gradually breaks down, which increases stiffness and makes it hard for aggression-damaged tissue to recover. This deterioration of collagen functionality can lead to loss of elasticity and the subsequent appearance of the wrinkles and dryness characteristic of old age. Various studies report that the process of cell ageing is slowed down by the consumption of monounsaturated fatty acids from plants, olive oil especially.

In a trial conducted on 1,264 women and 1,677 men between the ages of 45 and 60, Latreille (26) observed fewer signs of skin ageing (lower incidence of photoageing, wrinkles and dryness) among the subjects with a higher intake of virgin olive oil. Specific fatty acids present in the olive fruit have been found to restore the antioxidant enzymes in skin keratinocytes and fibroblasts (27), the cells that produce elastin, an essential component of the dermis which lends it firmness and elasticity. This ability of virgin olive oil and olive derivatives has led to their extensive use in cosmetics because they improve skin appearance and may also reduce the emergence of age spots and sun-induced blemishes. Hydroxytyrosol, one of the polyphenols specific to the olive (it is found in olive leaves and extra virgin olive oil whereas it is lost in refining processes), has notable depigmenting properties in that it inhibits the uncontrolled accumulation of melanin (skin spots) by acting on melanocytes, the cells that produce melanin.

Effect of olive oil on life expectancy

Findings of research conducted on different populations (28-30) has found that due to its content of oleic acid and monounsaturated fatty acids, consumption of virgin olive oil is associated with lower mortality in elderly subjects. This decrease in overall mortality is also associated with a higher level of blood carotenoids and increased tocopherol and vitamin E. Virgin olive oil is an important source of vitamins, namely vitamin A (strengthens the body's defences), vitamin D (anti-rickets properties), vitamin E (antioxidant effect on cell membrane) and vitamin K (anti-haemorrhagic).

In contrast, no negative health effect has been observed as a result of consuming olive oil. Nevertheless, like any fat, it has a high calorie count (9 kcal/g), and should therefore be consumed in moderation (maximum 4 tablespoonfuls per day) although regularly.

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Importance of olive oil in the prevention of overweight, development and sexual precocity in adolescent girls

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Resumen

El aumento del sobrepeso y la obesidad en la infancia y la adolescencia afectan de una manera preocupante a los países desarrollados y en vías de desarrollo. En Estados Unidos la situación es grave, pero resulta aún más alarmante en los países del Mediterráneo, ya que éstos se caracterizan por uno de los estilos nutricionales más saludables del mundo.

Las consecuencias del sobrepeso y de la obesidad son bien conocidas: problemas osteoarticulares, cardiovasculares, metabólicos y hasta psicológicos. La industrialización, la globalización y la aculturación han producido un cambio en los hábitos nutricionales de muchas regiones, con un aumento importante en la ingesta de grasas saturadas. Ahora vemos además, la incidencia que sobre el desarrollo sexual de las adolescentes tiene el alejarse de la Dieta Mediterránea; y sobre todo la reducida ingesta de su pilar fundamental, el aceite de oliva (virgen y virgen extra en máximo grado), con consecuencias como menarquia adelantada, pubertad precoz, precocidad sexual y disfunciones sexuales.

Palabras clave

Pubertad precoz. Menarquia. Disfunciones sexuales. Precocidad sexual. Dieta Mediterránea. Aceite de oliva virgen.

Abstract

The increase in overweight and obesity in childhood and adolescence is a cause for concern in both developed and developing countries. While the situation is serious in the United States, it is even more alarming in the Mediterranean countries which are characterised by one of the healthiest dietary styles in the world.

The consequences of overweight and obesity are well known: bone, joint, cardiovascular, metabolic and even psychological problems. Industrialisation, globalisation and acculturation have produced changes in nutritional habits in many regions, bringing with them a large increase in saturated fat intake. In addition, the move away from the Mediterranean diet and the low intake of olive oil (virgin and especially extra virgin), its fundamental pillar,

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is also affecting the sexual development of teenage girls with consequences such as early menarche, precocious puberty, sexual precocity and sexual dysfunctions.

Key words

Precocious puberty; menarche; sexual dysfunctions; sexual precocity; Mediterranean diet; virgin olive oil.

Olives, the nutrition of the future - C. Barbieri

Overweight and obesity during childhood and adolescence

Overweight and obesity are the most frequent metabolic problems among the nutritional disorders observed during childhood and adolescence and have become a world public health epidemic (1). Some decades ago, a large increase in body weight started to be detected at all stages of life (2). Obesity is a global epidemic that affects developed and developing countries alike. In the United States 69% of the population is overweight and 36% is obese (3).

In Europe, this problem continues to grow steadily according to the International Obesity Task Force (IOTF). Paradoxically, the highest rates of overweight and obesity prevalence in childhood and adolescence (almost 40%) are being reached in the Mediterranean countries, the cradle of the outstanding Mediterranean diet. Of the 42 million children affected by obesity in the world, more than 15 million are currently estimated to be in Europe (4). In Spain, the recent nationwide ALADINO study (5) reports excess body weight (obesity plus overweight) in 44.5% of the population between the ages of 6 and 9; the breakdown between obesity and overweight is 18. 3% and 26. 2%, respectively. Until 2011, Italy led the ranking for this public health issue (3). Child obesity is not merely an aesthetic problem, nor is it devoid of serious long-term risks. Between 30% and 80% of obese children will become obese adults. Moreover, their treatment will pose more difficulties than that of subjects whose obesity started later in life.

It is estimated that 25-35% of cases of obesity occur in families where the parents are normal weight although the risk is greater if the parents are obese (6). The risk of child obesity is four times greater if one of the parents is obese and eight times greater if both are obese (7). Some dietary styles are healthier and therefore significantly improve not only life expectancy but also quality of life. The concept of the Mediterranean diet was first coined by Ancel and Margaret Keys in their renowned Seven Countries Study (8) in which it was observed that a diet low in saturated fats and high in the monounsaturated fats obtained from virgin olive oil afforded protection from cardiovascular diseases. The total lipid content of the Mediterranean diet was high in Greece (around 40% of total calories) and moderate in Italy (around 28% of total calorie intake) and the monounsaturate/saturate ratio was much higher than in the rest of the countries included in the Study (Finland, Netherlands, United States, ex-Yugoslavia and Japan). Follow-up of the Seven Countries Study demonstrated that coronary mortality was lower, the higher the value of this ratio (9). Consumption of virgin olive oil, coupled with regular intake of legumes, grains, vegetables, fruit and dairy products, moderate amounts of fish, and a small amount of wine in the case of wine drinkers, is an essential part of what is known today as the Mediterranean diet. This diet is considered to be the prototype of a healthy diet, the principles of which should be applied from childhood, which is very easy in the geographical environment of the Mediterranean.

Acculturation and industrialisation and the concomitant consumption of ever increasing amounts of processed food are bringing changes in preferences and habits, particularly in children and young people. While the resultant calorie intake may even be age-adequate for adolescents, the proportions of different nutrients are altered. Consumption of meat and meat derivatives and processed and refined products is too high while that of legumes, fruit, grains and fish is too low. Consumption of virgin olive oil is also lower than recommended in lipid intake, thus changing the ratio between dietary saturated and monounsaturated fats.

Interestingly, more cases of obesity and overweight are observed among schoolchildren who go home for lunch than among those who eat in school canteens, thus endorsing the success of school dietary campaigns. Obesity prevention is fundamental in the children of obese parents (11).

Educating through nutrition - C. Barbieri

In addition to the better known problems generated by overweight, its effect on sexual development in pubertal subjects started to be evaluated some years ago.

In the 20th century, in the wake of the wars that devastated Europe and the rest of the world, dietary consumption levels improved in terms of nutrient intake, for instance of animal proteins, but qualitative changes also occurred in recommended nutritional patterns. From that point onwards, increased industrialisation and globalisation made it easier to buy food, so encouraging overconsumption of proteins (meat and cold and processed meats) and less consumption of fruit, legumes, grains, fish and vegetables. In 2005 the Advisory Committee on Dietary Guidelines for Americans examined the importance of portion size on energy intake and concluded that it influenced the amount of food consumed. Although it seems evident, energy intake generally increased with larger serving portions than smaller-sized ones (12).

Numerous studies conducted on adults in various countries have demonstrated that the relation between excess protein consumption and lower vegetable intake leads to overweight, obesity and other morbidities. To cite some examples, Kahn *et al* (13) evaluated the changes in BMI (body mass index) and waist circumference in 79,236 adults who were monitored for 10 years. They observed that BMI increase was associated with increased consumption of meat and decreased consumption of plant-based foods. In 2006, Rosell *et al* (14) evaluated weight gain in 21,966 adults over a five-year period. After adjustment of confounding factors, weight gain was observed to be significantly smaller in volunteers who had switched to a diet with a lower content of foods of animal origin during the monitoring period. Similarly, when monitoring 8,401 volunteers in 2008, Vang (15) observed greater risk of significant weight gain associated with intake of red meat, poultry and processed meats (15). Vergnaud (16) evaluated the relationship between meat consumption (red meat, poultry and processed meat) and weight gain in adults. Five-year monitoring of the participants in the trial (270,348 women and 103,455 men) revealed a positive association between consumption of red meat, poultry and processed meats and higher BMI (16) after adjusting for confounding factors.

This issue is similar in childhood and adolescence and has global implications. Evaluation of more than 36,000 subjects revealed that the body weight of adolescent girls in country areas was higher than that of female teenagers in cities in the Republic of Iran where this problem is likewise considered a public health issue (17) (18). In Spain, the protein intake of more than 90% of children is higher than recommended while carbohydrate intake is lower. Also, the average proportion of daily energy derived from fat is higher than the recommended maximum in 80% of the children, chiefly due to a higher intake of saturated fats (the protein and saturated fat intake of 90. 6% of the children exceeds recommended levels).

Despite these data, Spain is not the country with the highest protein intake; the leaders are the United States, the United Kingdom, Argentina, Brazil and Uruguay. A shortage of monounsaturated fatty acids from virgin olive oil is observed together with higher cholesterol levels and increased risk of cardiovascular diseases and metabolic syndrome (19) (20).

Precocious puberty

There is clear evidence of the links between overweight, increased insulin secretion and sexual maturation (21) (22). Puberty is considered to be the final stage of child growth and development when final height is reached and reproductive and psychosocial capacity is attained in the young adolescent. The central nervous system (CNS) initiates sexual development via the hypothalamic-pituitary-gonadal axis (HPG). This is controlled genetically besides having an important environmental component (23). Gonadotropin-releasing hormone (GnRH), growth hormone releasing hormones (GHRH) and somatostatin are produced in the hypothalamus. The anterior pituitary releases follicle-stimulating hormone (FSH) and luteinising hormone (LH), as well as growth hormone (GH). The ovaries and testes produce mature gametes (oocytes and sperm) and sex steroids (progestogens, oestrogens, androgens and inhibins). An increase also occurs in insulin-like growth factors (IGFs) such as insulin-like growth factor 1 (IGF-1), which stimulates ovary follicle maturation, oestrogen production and the gonadotropin-releasing hormone (GnRH). All of this is conducive to sexual maturation and pubertal growth spurt (24).

Precocious puberty is defined as the early, progressive appearance of signs of puberty at a chronological age 2.5 standard deviations (SD) below the mean age of puberty onset (2 SD below in the United States) (23). If it is LHRH gonadotropin-dependent or dependent on early activation of the LHRH hypothalamic pulse generator, it is called central or true precocious puberty or complete isosexual precocity (idiopathic, CNS lesions, congenital, acquired or tumoral). If it is gonadotropin-independent, it is known as peripheral precocious puberty or incomplete isosexual precocity (due to sex steroid- or gonadotropin-secreting tumours, congenital adrenal hyperplasia and McCune-Albright syndrome amongst other things) (25). Precocious puberty is five times more frequent in females than in males and occurs in girls with a high BMI or tendency to obesity or rapid weight gain (26).

Differences in metabolism at rest and total energy expenditure of pre-pubertal adolescents are associated with parental weight and ethnic group (27) while differences in energy expenditure are associated with the pubertal stage and race (28). White overweight girls are more likely to develop precocious puberty.

In male children, overweight and obesity can cause alterations in pubertal development and induce early puberty. Most obese children are above the 50th size percentile for their age. A large percentage of such children display early linear growth, early bone age and precocious sexual maturation and pubertal spurt. Nevertheless, some reach a relatively low average height in adulthood. Pseudohypogenitalism is a very frequent problem in pre-pubertal males because suprapubic fat overshadows the base of the penis, making it look smaller (29). Gynecomastia is another frequent problem in males owing to fat accumulation in the breast area, generally without any real increase in glandular breast tissue.

The average age at which girls have their first menstruation (menarche) has dropped sharply since the middle of the 20th century, although it now appears to be levelling. It is currently known that this was due to easier access to nutrients, increased sedentarism and higher levels of overweight and obesity, with the ensuing hormonal consequences (30). Paediatricians in Spain have observed that the age of menarche has dropped to just over the age of 12 (30). Rapid weight gain up to 45 kg can induce menstruation at the age of 9 in female children, and even at the age of 4 according to Professor Moreno Esteban (31). Similarly, ongoing studies (33) of immigrant female children (32) report that improved intake capacity encourages the early onset of sexual development (32).

Other research reports a strong link between meat consumption in early infancy and early menarche (34). Not only does meat consumption cause earlier sexual development, it also supplies fat with a high content of zinc and iron. Curiously, these two minerals are essential during pregnancy; this is why a meat-rich diet may perhaps be laying the right nutritional conditions for pregnancy development and maintenance. Additionally, a 75% increase was observed in the probability of menarche at the age of 12 in females who consumed more meat and meat derivatives compared with those who consumed less. Although this result did not take into account body weight, other research conducted in the past has shown that menstruation tends to start earlier in girls who are heavier in weight.

Not only has excess saturated fat consumption been observed to encourage sexual development per se; it also alters the correct proportions of unsaturated fats, especially monounsaturates (virgin olive oil). To cite one instance, a study conducted on children in Granada (35) reported that they consumed a diet in which 57% of calorie intake was from fats, split between monounsaturates (20%), polyunsaturates (10%) and saturates (27%). This type of diet leads to the harmful effects of excess saturates such as increased LDL cholesterol, which alters the benefits of the monounsaturated fatty acids. It should not be overlooked that a healthy, balanced, palatable diet for children and adolescents can contain a daily content of 30% virgin olive oil (36).

Continuing along the same line of thought, it has also been observed that intake of zinc, folic acid and vitamins D and E is lower in both sexes and female intake of iron and vitamin B6 is lower than that recommended for this population group. This is corroborated by studies conducted on subjects of both sexes between the ages of 5 and 12 in the Autonomous Community of Madrid. There is a greater tendency to display eating disorders (20) such as anorexia and bulimia among individuals suffering from overweight and obesity. In such subjects, bone maturation is faster and accompanied by early sealing of the growth plates and final low height, bearing in mind that pubertal growth accounts for 15–20% of adult height (37).

The dangers of rapid weight gain. C. Barbieri

Sexual precocity, aggression and nutrition-related alterations

Body maturity reached in adolescence does not coincide with psychological maturity. Children with early puberty have different patterns of behaviour and social adjustment from pre-school years through to early adolescence. At least in part, the association between early-onset puberty and behavioural difficulties appears to result from processes underway well before the onset of puberty (38). Studies (39) show that early puberty, early sex, unprotected sexual intercourse in adolescence and the number of sexual partners in early adulthood are closely linked, although there is not sufficient medical literature to separate this problem from its socio-cultural aspects. Cases have been documented of children suffering from true precocious puberty becoming pregnant at the age of 5, clearly as a result of sexual abuse (40). Child sexual abuse is quite common and will affect one of every three women and one of every eight men. Sexual precocity in girls with the body of a woman but the mind of a child can attract attacks from sexual predators, resulting in unwanted pregnancies, besides leading to an increase in the number of potential aggressions. Also, a history of sexual abuse in childhood is associated with numerous psychological effects including depression, anxiety, eating disorders, substance abuse and somatisation. Besides suffering terrible psychological trauma, the victims of such abuse show greater predisposition to nutrition-related metabolic disorders (41).

Conclusions

Child overweight and obesity are reaching really alarming proportions. These disorders are heightened by the availability of easy-to-eat processed foods, the decrease in physical activity, aggravated nowadays by new technologies, and the loss of adherence to the Mediterranean Diet and resultant decrease in the consumption of fruit, legumes, grains and fish and lower intake of virgin olive oil in favour of alternatives (increase in animal proteins, fast food, industrial bakery products, sugary drinks). The problems generated are only too well known and have cardiovascular, bone and joint, metabolic and psychological effects besides placing an exorbitant financial burden on health services. Any action to change this state of affairs from childhood through training, communication and education will be extremely useful. The ratio between saturated and unsaturated fats has to be improved to avoid the complications mentioned. In our environment we must consume more virgin olive oil, with extra virgin in pride of place, and return to the Mediterranean diet. In this article we have set out to highlight the enormous impact of overweight and obesity on sexual development in adolescence in the form of early-onset puberty, precocious puberty, lower final height, sexual precocity and increased vulnerability to serious metabolic disorders that may lead to social and behavioural problems.

Illustrated by Carlos Barbieri, painter, illustrator and graphic artist; Penagos Award. Contributor to La Codorniz, Tiempo, Diario 16, ABC.

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