



METHOD OF ANALYSIS

DETERMINATION OF THE COMPOSITION AND CONTENT OF STEROLS, TRITERPENIC DIALCOHOLS AND ALIPHATIC ALCOHOLS BY CAPILLARY COLUMN GAS CHROMATOGRAPHY

1. SCOPE

The method describes a procedure for determining the individual and total alcoholic compound content of olive oils and olive pomace oils as well as of blends of these two oils.

The alcoholic compounds in olive and olive pomace oils comprise aliphatic alcohols, sterols and triterpenic dialcohols.

2. PRINCIPLE

The oils, with added α -cholestanol and 1-eicosanol as internal standards (I.S.), are saponified with potassium hydroxide in ethanolic solution and the unsaponifiable matter is then extracted with diethyl ether.

The different alcoholic compounds fractions are separated from the unsaponifiable matter either by thin-layer chromatography (TLC) on a basic silica gel plate (reference method) or by HPLC with a silica gel column. The fraction recovered from the silica gel separation is transformed into trimethylsilyl ethers and then analysed by capillary column gas chromatography.

PART 1. PREPARATION OF THE UNSAPONIFIABLE MATTER

1. SCOPE

This part describes the preparation and extraction of the unsaponifiable matter from olive and olive-pomace oils.

2. PRINCIPLE

A test portion is saponified by boiling under reflux with an ethanolic potassium hydroxide solution. The unsaponifiable matter is extracted with diethyl ether.

3. APPARATUS

The usual laboratory equipment and in particular the following:

- 3.1. Round bottomed flask fitted with a reflux condenser with ground-glass joints, 250 mL.
- 3.2. Separating funnel, 500 mL.
- 3.3. Flasks, 250 mL.
- 3.4. Microsyringes, 100 μ L and 500 μ L.
- 3.5. Cylindrical filter funnel with a G3 porous septum (porosity 15-40 μ m) of diameter approximately 2 cm and a depth of 5 cm, suitable for filtration under vacuum with male ground-glass joint.
- 3.6. Conical flask with ground-glass female joint, 50 mL which can be fitted to the filter funnel (3.5).
- 3.7. Test tube with a tapering bottom and a sealing glass stopper, 10 mL.
- 3.8. Calcium dichloride desiccator.

4. REAGENTS

4.1. Pure materials

- 4.1.1. Potassium hydroxide, analytical grade, $\geq 85\%$.
- 4.1.2. Diethyl ether, chromatography grade.
- 4.1.3. Acetone, chromatography grade.
- 4.1.4. Ethanol, analytical grade.
- 4.1.5. Ethyl acetate, analytical grade.
- 4.1.6. Anhydrous sodium sulphate, analytical grade.
- 4.1.7. α -cholestanol, $\geq 95\%$ (by GC analysis).
- 4.1.8. 1-eicosanol, $\geq 98\%$ (by GC analysis).
- 4.1.9. Phenolphthalein, analytical grade

4.2. Working solutions

- 4.2.1. Potassium hydroxide ethanolic solution, approximately 2 M. Dissolve 130 g of potassium hydroxide (4.1.1) with cooling in 200 mL of distilled water and then make up to 1 L with ethanol (4.1.4). Keep the solution in well-stoppered dark glass bottles and use within 2 days.
- 4.2.2. Internal standard solution of α -cholestanol (4.1.7), 0.2% (m/V) solution in ethyl acetate (4.1.5).
- 4.2.3. Internal standard solution of 1-eicosanol (4.1.8), 0.1% (m/V) solution of in ethyl acetate (4.1.5).
- 4.2.4. Phenolphthalein (4.1.9) solution, 10 g/L in ethanol (4.1.4).

5. PROCEDURE

Using a 500 μL micro-syringe (3.4) introduce into the 250 mL flask (3.1) a volume of the α -cholestanol (4.2.2) and a volume of 1-icosanol (4.2.3) internal standard solutions containing an amount of α -cholestanol and 1-icosanol corresponding to approximately 10% of the sterol and alcohol content of the sample. For example, for 5 g of olive oil sample add 500 μL of the α -cholestanol solution (4.2.2) and 250 μL of 1-icosanol solution (4.2.3). For pomace olive oils add 1500 μL of both α -cholestanol solution (4.2.2) and 1-icosanol solution (4.2.3). Evaporate until dryness with a gentle current of nitrogen in a warm water bath. After cooling the flask, weigh 5.00 ± 0.01 g of the dry filtered sample into the same flask.

Note 1: Animal or vegetable oils and fats containing appreciable quantities of cholesterol may show a peak having a retention time identical to α -cholestanol. If this case occurs that the sterol fraction will have to be analysed in duplicate with and without internal standard.

Add 50 mL of 2M ethanolic potassium hydroxide solution (4.2.1) and some pumice, fit the reflux condenser and heat to gentle boiling until saponification takes place (the solution becomes clear). Continue heating for a further 20 min, then add 50 mL of distilled water from the top of the condenser, detach the condenser and cool the flask to approximately 30 $^{\circ}\text{C}$.

Transfer the contents of the flask quantitatively into a 500 mL separating funnel (3.2) using several portions of distilled water (50 mL). Add approximately 80 mL of diethyl ether (4.1.2), shake vigorously for approximately 60 s, periodically releasing the pressure by inverting the separating funnel and opening the stopcock. Allow standing until there is complete separation of the two phases (Note 2). Then draw off the soap solution as completely as possible into a second separating funnel. Perform two further extractions on the water-alcohol phase in the same way using 60 to 70 mL of diethyl ether (4.1.2).

Note 2: Any emulsion can be destroyed by adding small quantities of ethanol (4.1.4).

Combine the three ether extracts in one separating funnel containing 50 mL of water. Continue to wash with water (50 mL) until the wash water no longer gives a pink colour on the addition of a drop of phenolphthalein solution (4.2.4). When the wash water has been removed, filter through anhydrous sodium sulphate (4.1.6) into a previously weighed 250 mL flask, washing the funnel and filter with small quantities of diethyl ether (4.1.2).

Evaporate the solvent by distillation in a rotary evaporator at 30 $^{\circ}\text{C}$ under vacuum. Add 5 mL of acetone (4.1.3) and remove the volatile solvent completely under a gentle current of nitrogen. Dry the residue in the oven at 103 ± 2 $^{\circ}\text{C}$ for 15 min. Cool in a desiccator and weigh to the nearest 0.1 mg.

PART 2. SEPARATION OF THE ALCOHOLIC COMPOUNDS FRACTIONS

1. SCOPE

The unsaponifiable matter prepared in Part 1 is fractionated in the different alcoholic compounds, such as aliphatic alcohols, sterols and triterpenic dialcohols (erythrodiol and uvaol).

2. PRINCIPLE

The unsaponifiable matter can be fractionated using basic thin layer chromatography (reference method), developed and the corresponding bands scrapped off and extracted. As an alternative

method of separation, HPLC using a silica gel column and UV detector can be used, and the different fractions collected. The aliphatic and triterpenic alcohols as well as the sterols and triterpenic dialcohols are isolated together.

3. APPARATUS

The usual laboratory equipment and in particular the following:

- 3.1. Complete apparatus for analysis by thin-layer chromatography using 20 x 20 cm glass plates.
- 3.2. Ultraviolet lamp with a wavelength of 366 or 254 nm.
- 3.3. Microsyringes, 100 μ L and 500 μ L.
- 3.4. Cylindrical filter funnel with a G3 porous septum (porosity 15-40 μ m) of diameter approximately 2 cm and a depth of 5 cm, suitable for filtration under vacuum with male ground-glass joint.
- 3.5. Conical flask with ground-glass female joint, 50 mL which can be fitted to the filter funnel (3.4).
- 3.6. Test tube with a tapering bottom and a sealing glass stopper, 10 mL.
- 3.7. Calcium dichloride desiccator.
- 3.8. HPLC system, consisting of:
 - 3.8.1. Binary pump
 - 3.8.2. Manual or automatic injector equipped with 200 μ L injection loop.
 - 3.8.3. In-line degasser.
 - 3.8.4. UV-VIS or IR detector
- 3.9. HPLC column (25 cm x 4 mm i.d.) with silica gel 60 (5 μ m particle size).
- 3.10. Syringe filter, 0.45 μ m.
- 3.11. Conical flask 25 mL.

4. REAGENTS

4.1. Pure materials

- 4.1.1. Potassium hydroxide, analytical grade, $\geq 85\%$.
- 4.1.2. Diethyl ether, chromatography grade.
- 4.1.3. Acetone, chromatography grade.
- 4.1.4. Ethanol, analytical grade.
- 4.1.5. Ethyl acetate, analytical grade.
- 4.1.6. n-Hexane, chromatography grade.
- 4.1.7. 2',7'-dichlorofluorescein
- 4.1.8. Glass 20x20 plates coated with silica gel, without fluorescence indicator, thickness 0.25 mm (commercially available ready for use).

4.2. Working solutions

- 4.2.1. Potassium hydroxide ethanolic solution, approximately 2 M. Dissolve 130 g of potassium hydroxide (4.1.1) with cooling in 200 mL of distilled water and then make up to 1 L with ethanol (4.1.4). Keep the solution in well-stoppered dark glass bottles and use within 2 days.
- 4.2.2. Potassium hydroxide ethanolic solution, approximately 0.2 M. Dissolve 13 g of potassium hydroxide (4.1.1) in 20 mL of distilled water and make up to 1 L with ethanol(4.1.4).
- 4.2.3. Reference solution for thin-layer chromatography: 5% solution of cholesterol or phytosterols, alcohols and erythrodiol in ethyl acetate (4.1.5).
- 4.2.4. Solution of 2',7'-dichlorofluorescein, 0.2% (m/V) in ethanol (4.1.4). Make slightly basic by adding a few drops of 2 M alcoholic potassium hydroxide solution (4.2.1).
- 4.2.5. *n*-Hexane (4.1.6)/diethyl ether (4.1.2) mixture 65:35 (V/V).
- 4.2.6. HPLC mobile phase *n*-hexane (4.1.6)/diethyl ether (4.1.2) 1:1 (V/V).

5. REFERENCE METHOD: SEPARATION OF THE ALCOHOLIC COMPOUNDS BY BASIC TLC

Preparation of the basic thin layer chromatography plates. Immerse or dip the silica gel plates (4.1.8) about 4 cm in the 0.2 M ethanolic potassium hydroxide solution (4.2.2) for 10 s, then allow to dry in a fume cupboard for 2 h and finally place in an oven at 100 °C for 1 h.

Remove from the oven and keep in a calcium chloride desiccator (3.7) until required for use (plates treated in this way must be used within 15 days).

Place *n*-hexane/diethyl ether mixture (4.2.5) (Note 3) into the development chamber, to a depth of approximately 1 cm. Close the chamber with the appropriate cover and leave thus for at least half an hour, in a cool place, so that liquid-vapour equilibrium is established. Strips of filter paper dipping into the eluent may be placed on the internal surfaces of the chamber. This reduces developing time by approximately one-third and brings about more uniform and regular elution of the components.

Note 3: The developing mixture should be replaced for every test, in order to achieve perfectly reproducible elution conditions, alternative solvent 50:50 (V/V) *n*-hexane/diethyl ether may be used.

Prepare an approximately 5% solution (m/V) of the unsaponifiable prepared in PART 1 in ethyl acetate (4.1.5) and, using the 100 µL microsyringe (3.3), depose 0.3 mL of the solution on a narrow and uniform streak on the lower end (2 cm) of the chromatographic plate (4.1.8). In line with the streak, place 2 to 3 µL of the material reference solution (4.2.3), so that the sterol, triterpene dialcohols and alcohols bands can be identified after developing.

Place the plate in the developing chamber (3.1). The ambient temperature should be maintained between 15 and 20 °C (Note 4). Immediately close the chamber with the cover and allow eluting until the solvent front reaches approximately 1 cm from the upper edge of the plate. Remove the plate from the developing chamber and evaporate the solvent in a flow of hot air or by leaving the plate for a short while, under a hood.

Note 4: Higher temperature could worsen the separation.

Spray the plate lightly and uniformly with the 2',7'-dichlorofluorescein solution (4.2.4) and then leave to dry. When the plate is observed under ultraviolet lamp (3.2), the sterols, triterpene

dialcohols and alcohols bands can be identified through being aligned with the spots obtained from the reference solution (4.2.3). Mark the limits of the bands along the edges of the fluorescence with a black pencil (see TLC plate in Figure 1).

By using a metal spatula, scrape off the silica gel of the marked area. Place the finely comminuted material removed into the filter funnel (3.4). Add 10 mL of hot ethyl acetate (4.1.5), mix carefully with the metal spatula and filter (under vacuum if necessary), collecting the filtrate in the conical flask (3.5.) attached to the filter funnel.

Wash the residue in the filter funnel three times with diethyl ether (4.1.2) (approximately 10 mL each time), collecting the filtrate in the same flask attached to the funnel. Evaporate the filtrate to a volume of 4 to 5 mL, transfer the residual solution to the previously weighed 10 mL test tube (3.6). Evaporate to dryness by mild heating, in a gentle flow of nitrogen, make up again using a few drops of acetone (4.1.3), evaporate again to dryness. The residue contained in the test tube consists of the sterols and triterpenic dialcohols or the aliphatic alcohols and triterpenic alcohols fractions.

6. SEPARATION OF THE ALCOHOLIC FRACTION BY HPLC

The unsaponifiable obtained from PART 1 is dissolved in 3 mL of the mobile phase (4.2.6), filter the solution with a syringe filter (3.10) and reserve.

Inject 200 μ L of the filtered unsaponifiable solution in the HPLC (3.8).

Run the HPLC separation at 0.8 mL/min, discard the first 5 min and collect in 25 mL conical flasks (3.11) between the 5 and 10 min for aliphatic and triterpenic alcohols and between 11 and 25 min for sterols and erythrodiol and uvaol (Note 5).

The separation can be monitored with an UV detector at 210 nm wavelength or a refractive index detector (see Figure 6).

The fractions are evaporated until dryness and prepared for chromatographic analysis.

Note 5. Carefully control the pressure of the HPLC pump, the diethyl ether can increase the pressure, adjust the flow to keep the pressure under control.

PART 3. GAS CHROMATOGRAPHIC ANALYSIS OF THE ALCOHOLIC COMPOUNDS FRACTIONS

1. SCOPE

This part gives general guidance for the application of capillary column gas chromatography to determine the qualitative and quantitative composition of the alcoholic compounds isolated in accordance with the method specified in PART 2 of this method.

2. PRINCIPLE

The fractions collected from the unsaponifiable matter using TLC or HPLC are derivatized into trimethylsilyl ethers and analysed by capillary column gas chromatography with split injection and flame ionization detector.

3. APPARATUS

The usual laboratory equipment and in particular the following:

- 3.1. Test tube with a tapering bottom and a sealing glass stopper, 10 mL.
- 3.2. Gas chromatograph suitable for use with a capillary column with split injection system, consisting of:
 - 3.2.1. A thermostatic chamber for columns capable of maintaining the desired temperature with an accuracy of ± 1 °C;
 - 3.2.2. A temperature-adjustable injection unit with a persilanised glass vaporising element and split system;
 - 3.2.3. A flame ionisation detector (FID);
 - 3.2.4. Data acquisition system suitable for use with the FID detector (3.10.3.), capable of manual integration.
- 3.3. Fused-silica capillary column of length 20 to 30 m, internal diameter 0.25 to 0.32 mm, coated with 5% Diphenyl - 95% Dimethylpolysiloxane (SE-52 or SE-54 stationary phase or equivalent), to a uniform thickness between 0.10 and 0.30 μm .
- 3.4. Microsyringe, of 10 μL capacity, for gas chromatography, with cemented needle suitable for split injection.

4. REAGENTS

- 4.1. Anhydrous pyridine, chromatography grade.
- 4.2. Hexamethyl disilazane, analytical grade.
- 4.3. Trimethylchlorosilane, analytical grade.
- 4.4. Sample solutions of sterol trimethylsilyl ethers. To be prepared at the time of use from sterols and erythrodiol obtained from oils containing them.
- 4.5. Standard solutions of trimethylsilyl ethers of aliphatic alcohols from C20 to C28. They may be prepared from mixtures of pure alcohols at the time they are required for use.
- 4.6. Carrier gas: hydrogen or helium, gas-chromatography grade.
- 4.7. Auxiliary gases: hydrogen, helium, nitrogen and air, of gas-chromatography grade.
- 4.8. Silylation reagent, consisting of a 9:3:1 (V/V/V) mixture of pyridine/hexamethyl disilazane/trimethylchlorosilane.
- 4.9. n-Hexane, for chromatography quality.

5. PREPARATION OF THE TRIMETHYLSILYL ETHERS (TMSE)

Add the silylation reagent (4.8) (Note 6), in the ratio of 50 μL for every milligram of alcoholic compound, in the test tube (3.1) containing the alcoholic compound fraction, avoiding any uptake of moisture (Note 7).

Note 6: Ready for use solutions are available commercially. Other silylation reagents, such as, for example, bistrimethylsilyl trifluoroacetamide + 1% trimethylchlorosilane, which has to be diluted with an equal volume of anhydrous pyridine, are also available. Pyridine can be replaced by the same amount of acetonitrile.

Note 7: The slight opalescence, which may form, is normal and does not cause any anomaly. The formation of a white

flock or the appearance of a pink colour is indicative of the presence of moisture or deterioration of the reagent. If these occur the test must be repeated (only if hexamethyldisilazane/trimethylchlorosilane is used).

Stopper the test tube (3.1), shake carefully (without overturning) until the compounds are completely dissolved. Leave to stand for at least 15 min at ambient temperature and then centrifuge for a few minutes. The clear solution is ready for gas chromatographic analysis.

6. GAS CHROMATOGRAPHIC ANALYSIS

6.1. Preliminary operations, capillary column conditioning

Fit the column (3.3) in the gas chromatograph, by attaching the inlet end to the split injector and the outlet end to the detector.

Carry out general checks on the gas chromatograph unit (leaks from the gas circuits, detector efficiency, efficiency of the splitting system and recording system, etc.).

If the column is being used for the first time, it is recommended that it should be subjected to conditioning: passing a gentle flow of gas through the column itself, then switch on the gas chromatography unit and begin a gradual heating, up to a temperature of at least 20 °C above the operating temperature (Note 8). Hold this temperature for at least 2 h, then place the entire unit in operating mode (adjustment of gas flows and splitting, ignition of the flame, connection with the computing system, adjustment of the column, detector and injector temperature, etc.) and then record the signal with a sensitivity at least two times greater than that one intended for the analysis. The course of the base line must be linear, without peaks of any kind, and must not show drift. A negative straight-line drift indicates leakage from the column connections; a positive drift indicates inadequate conditioning of the column.

Note 8: The conditioning temperature must always be at least 20 °C less than the maximum temperature specified for the stationary phase used.

6.2. Operating conditions

Optimize the temperature programme and the carrier gas flow so that chromatograms similar to Figure 2 to 5 are obtained.

The following parameters were tested and found useful:

6.2.1. Aliphatic alcohols

Oven Program	180 °C (8 min.) → 260 °C (at 5 °C/min) → 260 °C (15 min)
Injector Temperature	280 °C
Detector Temperature	290 °C
Linear Velocity of Carrier gas	Helium (20 to 30 cm/s); Hydrogen (30 to 50 cm/s)
Split Ratio	1:50 to 1:100
Volume Injected	0.5 to 1 µL of TMSE solution

6.2.2. Sterols and triterpenic dialcohols

Oven Program	260 ± 5 °C Isothermal
Injector Temperature	280 – 300 °C
Detector Temperature	280 – 300 °C
Linear Velocity of Carrier gas	Helium (20 to 30 cm/s); Hydrogen (30 to 50 cm/s)
Split Ratio	1:50 to 1:100
Volume Injected	0.5 to 1 µL of TMSE solution

These conditions may be changed according to the characteristics of the column and gas chromatograph, to obtain chromatograms, which meet the following requirements:

- Alcohol C26 retention time shall be 18 ± 5 min.
- Alcohol C22 peak shall be 80 ± 20% of the full-scale value for olive oil and 40 ± 20% of the full-scale value for olive-pomace oil.
- The retention time for the β-sitosterol peak should be at 20 ± 5 min.
- The campesterol peak should be: for olive oil (mean content 3%) 20 ± 5% of full scale.
- All the present sterols must be separated. In addition to being separated the peaks, they must also be completely resolved, i.e. the peak trace should return to the base line before leaving for the next peak. Incomplete resolution is, however, tolerated, provided that the peak at RRT 1.02 (sitostanol) can be quantified using the perpendicular.

6.3. Analytical procedure

By using the 10 µL microsyringe (3.4), take 1 µL of hexane, draw in 0.5 µL of air and then 0.5 to 1 µL of the sample solution. Raise the plunger of the syringe further, so the needle is emptied. Push the needle through the membrane of the injector and after 1 to 2 s, inject rapidly, and then slowly remove the needle after around 5 s. An automatic injector can be used as well.

Carry out the recording until the TMSE of the corresponding alcoholic compounds present are completely eluted. The base line must continue to meet the requirements of the corresponding operating conditions (6.2.1 or 6.2.2).

6.4. Peak identification

Identify individual peaks on the basis of retention times and by comparison with the mixture of the aliphatic and triterpenic alcohols or the sterol and triterpene dialcohols TMSE, analysed under the same conditions. A chromatogram of the aliphatic and triterpenic alcohols fraction is presented in Figure 4 and the corresponding chromatogram for sterols and triterpenic dialcohols are presented in Figure 2.

The aliphatic alcohols are eluted in the following order: C20-ol (I.S.), C22-ol, C23-ol, C24-ol, C25-ol, C26-ol, C27-ol and C28-ol.

The sterols and triterpenic dialcohols are eluted in the following order: cholesterol, α-cholestanol (I.S.), brassicasterol, ergosterol, 24-methylene-cholesterol, campesterol, campestanol, stigmasterol, Δ7-campesterol, Δ5,23-stigmastadienol, clerosterol, β-sitosterol, sitostanol, Δ5-avenasterol, Δ5,24-stigmastadienol, Δ7-stigmastanol, Δ7-avenasterol, erythrodiol and uvaol.

6.5. Quantification

6.5.1. Absolute concentration calculation

The peak areas of 1-eicosanol and of the aliphatic alcohols C22, C24, C26, C28 are calculated by a data acquisition system. The response factor for 1-eicosanol should be considered equal to 1.

Calculate the areas of the α -cholestanol peak, the sterols peaks, the erythrodiol peak and the uvaol peak by using the computing system. Ignore peaks for any compound, which are not included (ergosterol must not be calculated) among those listed in Table 1. The response factor for α -cholestanol should be considered equal to 1.

Calculate the concentration of each individual alcoholic compound (aliphatic alcohols, sterols, erythrodiol, uvaol), in mg/kg of fatty material, as follows:

$$\text{Alcoholic compound } x = \frac{A_x \times m_s}{A_s \times m} \times 1000$$

where:

A_x = Peak area for alcoholic compound x, in computing system counts.

A_s = Area of the I.S. peak (1-eicosanol for aliphatic alcohols, or α -cholestanol for sterols, erythrodiol and uvaol) in computing system counts.

m_s = Mass of added I.S. (1-eicosanol for aliphatic alcohols, or α -cholestanol for sterols, erythrodiol and uvaol), in milligrams.

m = Mass of the sample used for determination, in grams.

6.5.2. Relative composition calculation

Calculate the relative percentage of each individual sterol from the ratio of the relevant peak area to the total peak area for sterols:

$$\text{Sterol } x = \frac{A_x}{\Sigma A} \times 100$$

where:

A_x = Peak area for sterol x.

ΣA = Total peak area for sterols.

Calculate the relative percentage of apparent β -sitosterol, by summing up the percentages of the following sterols: Δ^5 -23-stigmastadienol + clerosterol + β -sitosterol + sitostanol + Δ^5 -avenasterol + Δ^5 -24-stigmastadienol.

Calculate the relative percentage of erythrodiol and uvaol:

$$\text{Erythrodiol} + \text{Uvaol} = \frac{A_{Er} + A_{Uv}}{\Sigma A_T} \times 100$$

where:

A_{Er} = Area of erythrodiol in computing system counts.

A_{Uv} = Area of uvaol in computing system counts.

ΣA_T = Sum of the areas for sterols + erythrodiol + uvaol in computing system counts.

7. EXPRESSION OF THE RESULTS

Report individual aliphatic alcohols, total aliphatic alcohols content, total sterols content and erythrodiol as mg/kg of fatty material. The total content for aliphatic alcohols is the sum of C22, C24, C26 and C28.

Report individual sterols as % of total sterols and erythrodiol+uvaol as % of the sum (total sterols+erythrodiol+uvaol).

The content in mg/kg of each of the individual aliphatic alcohols and of erythrodiol and the percentage (%) of individual sterols and of erythrodiol+uvaol should be expressed to one decimal place.

Total sterols and total aliphatic alcohols concentrations should be expressed without any decimal place.

APPENDIX

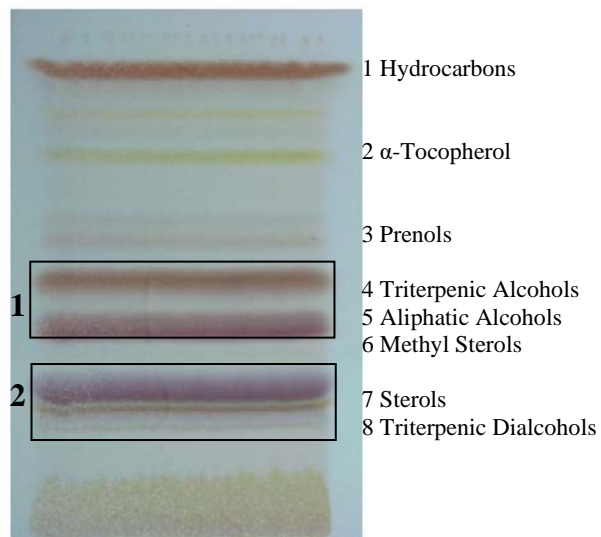


Figure 1. Thin-layer chromatography plate of the unsaponifiable fraction from olive pomace oil eluted twice with hexane:diethyl ether (65:35), developed with SO_4H_2 (50%) and heated. The bands that should be scrapped off are the contained within the rectangle, 1 are the bands for the aliphatic alcohols and 2 for the sterols and triterpenic dialcohols.

TABLE I
RELATIVE RETENTION TIMES FOR STEROLS

Peak	Identification		Relative retention Time	
			SE 54 column	SE 52 Column
1	cholesterol	Δ -5-cholesten-3 β -ol	0.67	0.63
2	α -cholestanol	5 α -cholestan-3 β -ol	0.68	0.64
3	brassicasterol	[24S]-24-methyl- Δ -5,22-cholestadien-3 β -ol	0.73	0.71
*	ergosterol	[24S] 24 methyl- Δ -5,7,22-cholestatrien-3 β -ol	0,78	0,76
4	24-methylene-cholesterol	24-methylene- Δ -5,24-cholestadien-3 β -ol	0.82	0.80
5	campesterol	(24R)-24-methyl- Δ -5-cholesten-3 β -ol	0.83	0.81
6	campestanol	(24R)-24-methyl-cholestan-3 β -ol	0.85	0.82
7	stigmasterol	(24S)-24-ethyl- Δ -5,22-cholestadien-3 β -ol	0.88	0.87
8	Δ -7-campesterol	(24R)-24-methyl- Δ -7-cholesten-3 β -ol	0.93	0.92
9	Δ -5,23-stigmastadienol	(24R,S)-24-ethyl- Δ -5,23-cholestadien-3 β -ol	0.95	0.95
10	cleroesterol	(24S)-24-ethyl- Δ -5,25-cholestadien-3 β -ol	0.96	0.96
11	β -sitosterol	(24R)-24-ethyl- Δ -5-cholesten-3 β -ol	1.00	1.00
12	sitostanol	24-ethyl-cholestan-3 β -ol	1.02	1.02
13	Δ -5-avenasterol	(24Z)-24-ethylidene- Δ 5-cholesten-3 β -ol	1.03	1.03
14	Δ -5-24-stigmastadienol	(24R,S)-24-ethyl- Δ -5,24-cholestadien-3 β -ol	1.08	1.08
15	Δ -7-stigmastenol	(24R,S)-24-ethyl- Δ -7-cholesten-3 β -ol	1.12	1.12
16	Δ -7-avenasterol	(24Z)-24-ethylidene- Δ -7-cholesten-3 β -ol	1.16	1.16
17	erythrodiol	5 α olean-12en-3 β 28 diol	1,41	1,41
18	uvaol	Δ 12-ursen-3 β 28 diol	1,52	1,52

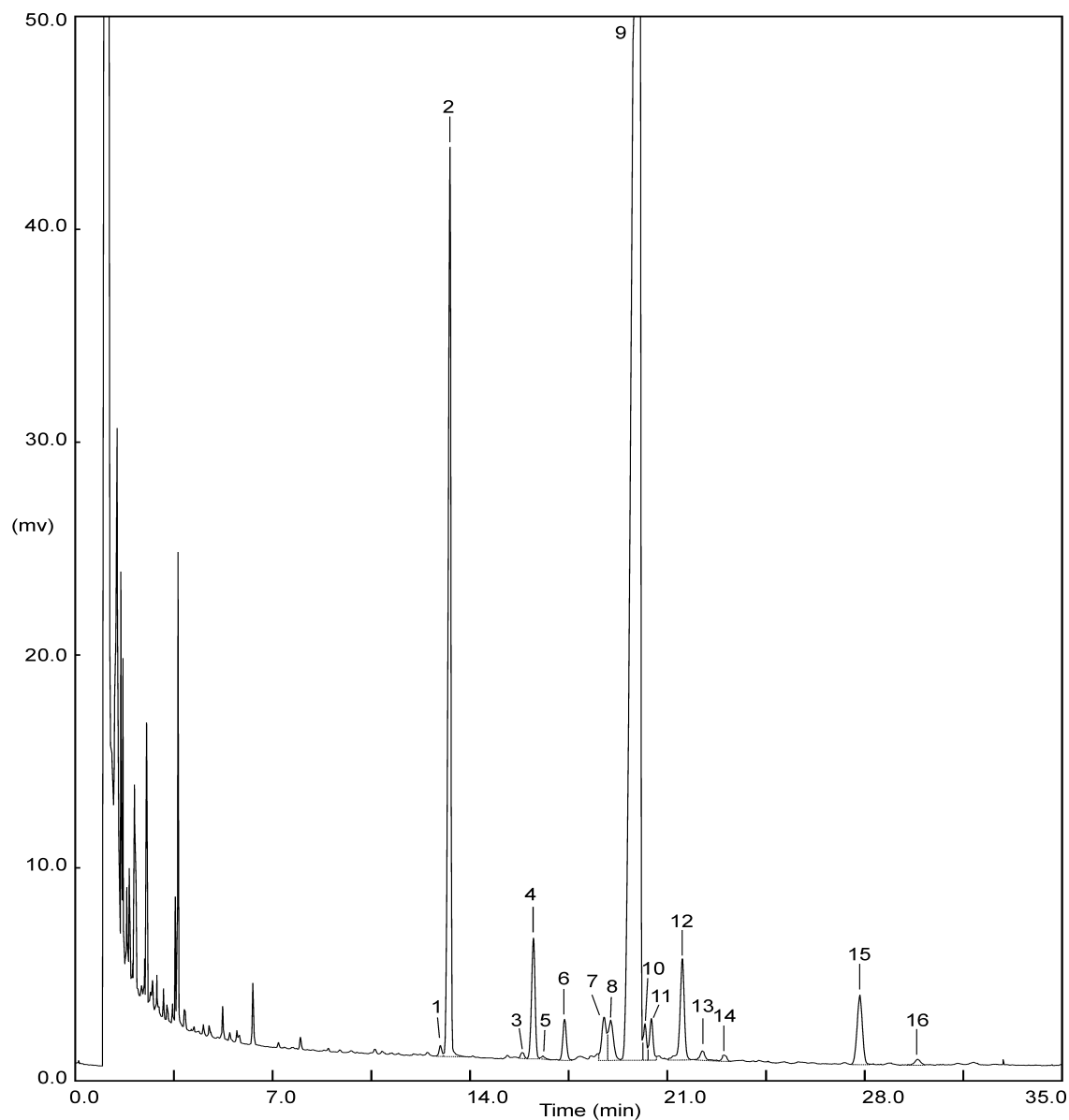


Figure 2. GC-FID chromatographic profile of the sterols and triterpenic dialcohols from refined olive oil. (1) cholesterol, (2) α -cholestanol (I.S.), (3) 24-methylene-cholesterol, (4) campesterol, (5) campestanol, (6) stigmasterol, (7) Δ 5,23-stigmastadienol, (8) clerosterol, (9) β -sitosterol, (10) sitostanol, (11) Δ 5-avenasterol, (12) Δ 5,24-stigmastadienol, (13) Δ 7-stigmastenol, (14) Δ 7-avenasterol, (15) erythrodiol, (16) uvaol.

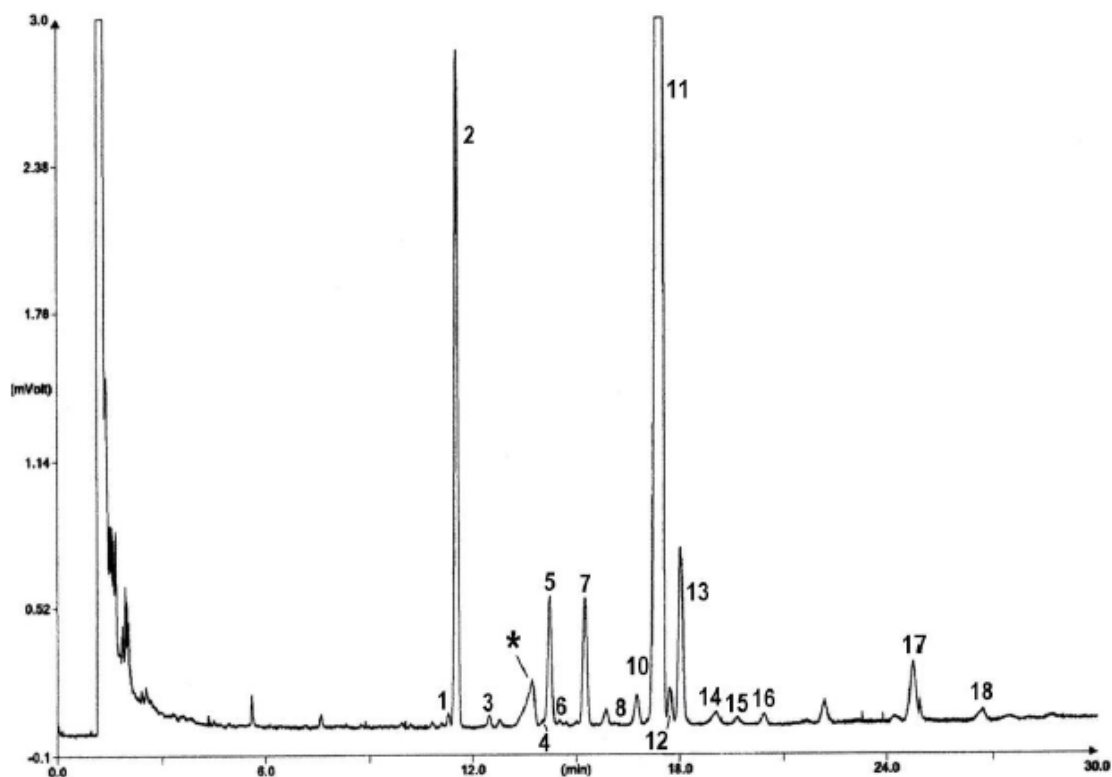


Figure 3. GC-FID chromatographic profile of the sterols and triterpenic dialcohols from a lampante olive oil. (1) cholesterol, (2) α -cholestanol (I.S.), (3) brassicasterol, (4) 24-methylene-cholesterol, (5) campesterol, (6) campestanol, (7) stigmasterol, (8) Δ 7-campesterol, (10) clerosterol, (11) β -sitosterol, (12) sitostanol, (13) Δ 5-avenasterol, (14) Δ 5,24-stigmastadienol, (15) Δ 7-stigmastenol, (16) Δ 7-avenasterol, (17) erythrodiol, (18) uvaol.

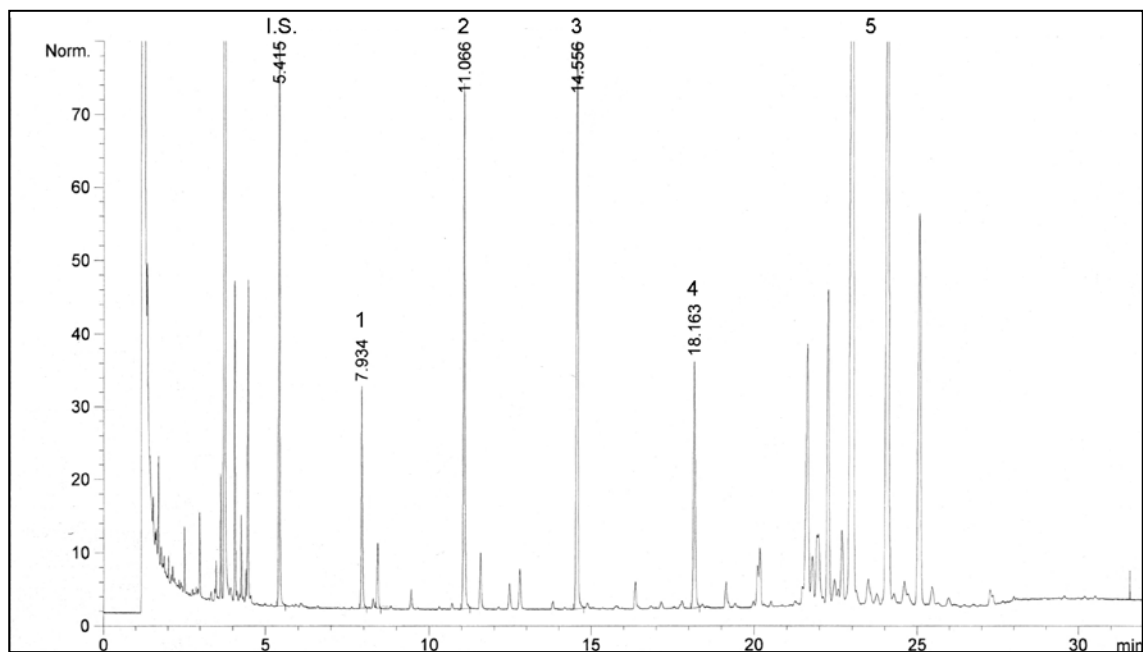


Figure 4. GC-FID chromatographic profile of aliphatic alcohols and triterpenic alcohols of olive oil. (I.S.) C20-ol, (1) C22-ol, (2) C24-ol, (3) C26-ol, (4) C28-ol, (5) triterpenic alcohols.

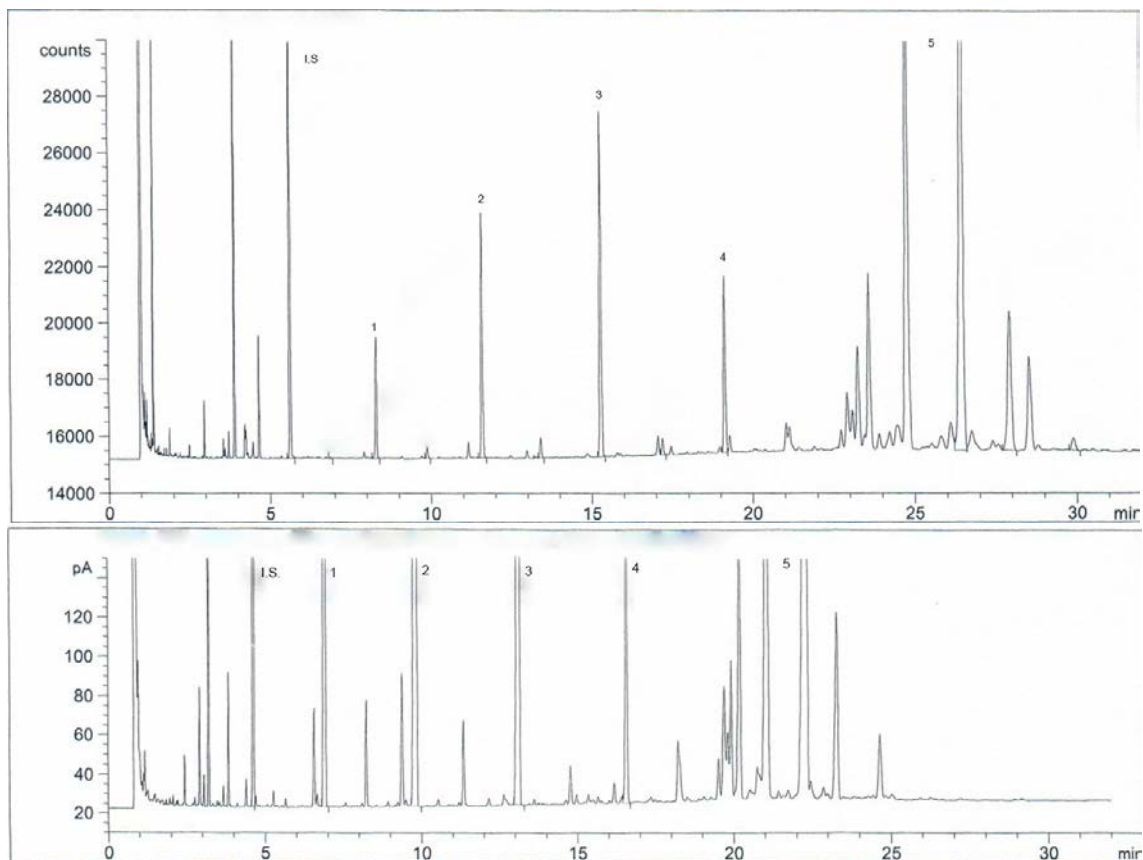


Figure 5- GC-FID chromatographic profile of aliphatic alcohols and triterpenic alcohols of a refined olive oil and a second centrifugation olive oil. (I.S.) C20-ol, (1) C22-ol, (2) C24-ol, (3) C26-ol, (4) C28-ol, (5) triterpenic alcohols.

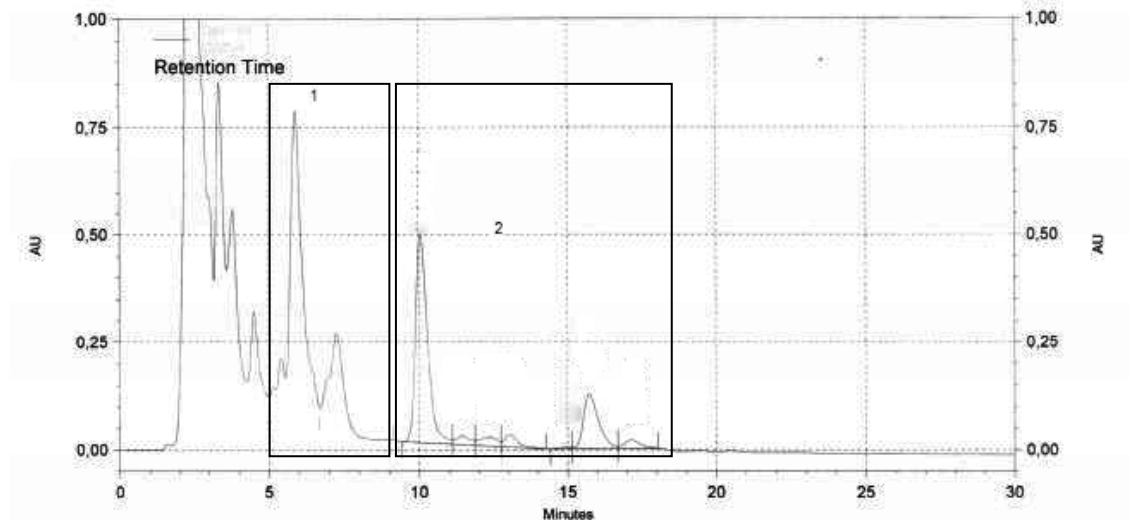


Figure 6. HPLC Chromatogram of an olive oil unsaponifiable separated by HPLC using a UV detector. (1) Aliphatic and triterpenic alcohols; (2) Sterols and triterpenic dialcohols.

PRECISION VALUES OF THE METHOD

1. Analysis of the collaborative test results for sterol content and alcoholic compounds:

The precision values of the method are given in the table on the next page for each parameter studied:

n	number of laboratories which participated in the test
outliers	number of laboratories with outlying values
mean	mean of the accepted results
r	repeatability
S_r	repeatability standard deviation
RSD_r(%)	repeatability coefficient of variation ($S_r \times 100 / \text{mean}$)
R	reproducibility
S_R	reproducibility standard deviation
RSD_R(%)	reproducibility coefficient of variation ($S_R \times 100 / \text{mean}$)

Results of interlaboratory test to separate the unsaponifiable fraction by TLC and HPLC of the sterol and alcohol fraction. Evaluation of the absolute content of erythrodiol and uvaol. An interlaboratory test was carried out in 2016 in accordance with ISO 5725. The results are summarised in Tables A.1 to A.22.

A: extra virgin olive oil from picual variety

B: lampante olive oil

C: olive oil + 10% sunflower oil

D: high oleic sunflower + 50 mg/kg erythrodiol + 20 mg/kg uvaol

E: virgin olive oil + refined olive pomace oil

Table A.1— Cholesterol (% total sterols) by Reference Method (TLC)

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	0	0	1	0	0
mean (%)	0.1	0.3	0.1	0.1	0.1
r	0.03	0.10	0.05	0.07	0.03
S_r	0.01	0.04	0.02	0.03	0.01
RSD_r(%)	8.3	13.6	14.2	20.2	8.6
R	0.06	0.28	0.09	0.14	0.07
S_R	0.02	0.10	0.03	0.05	0.02
RSD_R(%)	15.9	37.5	22.5	40.3	23.4

Table A.2— Cholesterol (% total sterols) by HPLC

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	0	0	0	0	0
mean (%)	0.1	0.3	0.1	0.1	0.1
r	0.03	0.10	0.07	0.03	0.04
S _r	0.01	0.04	0.02	0.01	0.01
RSD _r (%)	7.6	15.0	17.7	9.3	10.8
R	0.06	0.24	0.09	0.11	0.06
S _R	0.02	0.08	0.03	0.04	0.02
RSD _R (%)	16.5	34.3	23.2	35.4	16.7

Table A.3— Brassicasterol (% total sterols) by Reference Method (TLC)

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	1	0	0	1	1
mean (%)	0.0	0.0	0.0	0.0	0.1
r	0.02	0.03	0.03	0.02	0.02
S _r	0.01	0.01	0.01	0.01	0.01
RSD _r (%)	68.1	23.6	39.3	25.3	14.7
R	0.03	0.11	0.09	0.07	0.15
S _R	0.01	0.04	0.03	0.03	0.05
RSD _R (%)	103.7	90.5	105.3	94.5	90.7

Table A.4— Brassicasterol (% total sterols) by HPLC

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	0	1	0	1	0
mean (%)	0.0	0.0	0.0	0.0	0.0
r	0.01	0.02	0.02	0.02	0.03
S _r	0.004	0.01	0.01	0.01	0.01
RSD _r (%)	23.9	19.9	30.0	35.6	22.5
R	0.04	0.06	0.05	0.04	0.09
S _R	0.02	0.02	0.02	0.01	0.03
RSD _R (%)	90.3	68.0	88.7	83.3	79.8

Table A.5— Campesterol (% total sterols) by Reference Method (TLC)

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	2	0	0	0	1
mean (%)	3.1	3.2	3.9	8.3	3.1
r	0.22	0.15	0.26	0.18	0.15
S _r	0.08	0.06	0.09	0.06	0.05
RSD _r (%)	2.6	1.7	2.4	0.8	1.7
R	0.25	0.39	0.45	0.78	0.27
S _R	0.09	0.13	0.16	0.28	0.10
RSD _R (%)	2.9	4.3	4.1	3.4	3.1

Table A.6— Campesterol (% total sterols) by HPLC

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	0	1	0	0	0
mean (%)	3.0	3.3	3.9	8.4	3.2
r	0.12	0.13	0.18	0.22	0.11
S _r	0.04	0.05	0.06	0.08	0.04
RSD _r (%)	1.5	1.4	1.6	0.9	1.3
R	0.48	0.59	0.37	0.52	0.28
S _R	0.17	0.21	0.13	0.18	0.10
RSD _R (%)	5.7	6.5	3.4	2.2	3.2

Table A.7— Stigmasterol (% total sterols) by Reference Method (TLC)

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	0	0	0	1	0
mean (%)	1.1	2.4	2.0	7.2	1.3
r	0.07	0.16	0.25	0.12	0.09
S _r	0.02	0.06	0.09	0.04	0.03
RSD _r (%)	2.1	2.4	4.5	0.6	2.5
R	0.18	0.29	0.41	0.62	0.11
S _R	0.06	0.10	0.15	0.22	0.04
RSD _R (%)	5.9	4.3	7.4	3.1	3.0

Table A.8— Stigmasterol (% total sterols) by HPLC

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	0	0	0	1	0
mean (%)	1.1	2.4	2.0	7.2	1.3
r	0.07	0.14	0.08	0.21	0.16
S _r	0.03	0.05	0.03	0.08	0.06
RSD _r (%)	2.3	2.1	1.5	1.1	4.4
R	0.15	0.22	0.11	0.45	0.19
S _R	0.06	0.08	0.04	0.16	0.07
RSD _R (%)	5.1	3.3	2.0	2.2	5.3

Table A.9— Apparent β -Sitosterol (% total sterols) by Reference Method (TLC)

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	0	0	1	1	1
mean (%)	94.4	92.6	89.0	61.1	94.0
r	0.45	0.37	1.43	1.43	0.33
S _r	0.16	0.13	0.51	0.51	0.12
RSD _r (%)	0.17	0.14	0.57	0.84	0.13
R	0.76	1.31	1.79	4.00	0.63
S _R	0.27	0.47	0.63	1.43	0.23
RSD _R (%)	0.29	0.51	0.72	2.34	0.24

Table A.10 — Apparent β -Sitosterol (% total sterols) by HPLC

Sample	A	B	C	D	E
n	15	15	15	15	14
outliers	0	0	1	1	1
mean (%)	94.4	92.5	88.7	60.7	94.1
r	0.38	0.45	1.15	1.08	0.50
S _r	0.13	0.16	0.41	0.39	0.18
RSD _r (%)	0.14	0.17	0.46	0.63	0.19
R	0.81	1.11	1.41	4.04	0.99
S _R	0.29	0.40	0.51	1.44	0.35
RSD _R (%)	0.31	0.43	0.57	2.38	0.38

Table A.11 — Δ^7 -Stigmastenol (% total sterols) by Reference Method (TLC)

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	0	0	0	0	1
mean (%)	0.3	0.4	3.2	16.0	0.5
r	0.06	0.08	0.53	1.08	0.06
S _r	0.02	0.03	0.19	0.39	0.02
RSD _r (%)	7.5	6.4	5.9	2.4	4.4
R	0.15	0.19	0.83	1.52	0.19
S _R	0.05	0.07	0.30	0.54	0.07
RSD _R (%)	18.7	16.0	9.4	3.4	13.5

Table A.12 — Δ^7 -Stigmastenol (% total sterols) by HPLC

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	1	0	0	0	0
mean (%)	0.32	0.46	3.22	16.09	0.52
r	0.10	0.12	0.38	0.75	0.08
S _r	0.037	0.041	0.13	0.267	0.029
RSD _r (%)	11.4	9.0	4.2	1.7	5.6
R	0.13	0.24	0.75	1.95	0.16
S _R	0.045	0.087	0.269	0.696	0.058
RSD _R (%)	14.2	18.8	8.3	4.3	11.0

Table A.13 — Total Sterols content (mg/kg) by Reference Method (TLC)

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	1	0	0	1	1
mean (mg/kg)	1572	1742	1679	2830	3181
r	84.9	134.8	144.7	246.2	307.3
S _r	30.3	48.1	51.7	87.9	109.7
RSD _r (%)	1.9	2.8	3.1	3.1	3.5
R	291.3	495.9	321.6	346.4	610.4
S _R	104.0	177.1	114.8	123.7	218.0
RSD _R (%)	6.6	10.2	6.8	4.4	6.9

Table A.14 — Total Sterols content (mg/kg) by HPLC

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	1	1	1	1	0
mean (mg/kg)	1583	1754	1730	2897	3216
r	74.0	93.5	95.0	59.01	181.9
S _r	264.4	33.4	33.9	21.1	65.0
RSD _r (%)	1.7	1.9	2.0	0.7	2.0
R	315.0	190.2	156.6	230.2	480.2
S _R	112.5	67.9	55.9	82.2	171.5
RSD _R (%)	7.1	3.9	3.2	2.8	5.3

Table A.15 — Erythrodiol + uvaol (% total sterols) by Reference Method (TLC)

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	1	0	1	0	0
mean (%)	2.1	3.8	1.2	2.5	17.2
r	0.32	0.34	0.19	0.27	0.76
S _r	0.12	0.12	0.07	0.10	0.27
RSD _r (%)	5.4	3.2	5.4	3.9	1.6
R	0.80	0.85	0.53	1.09	4.68
S _R	0.29	0.30	0.19	0.39	1.67
RSD _R (%)	13.3	8.0	15.3	15.5	9.7

Table A.16 — Erythrodiol + uvaol (% total sterols) by HPLC

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	0	0	0	0	0
mean (%)	2.2	3.8	1.4	2.0	17.2
r	0.40	0.32	0.24	0.16	0.73
S _r	0.14	0.11	0.09	0.06	0.26
RSD _r (%)	6.5	3.0	6.1	2.8	1.5
R	0.52	0.57	0.46	0.62	3.66
S _R	0.19	0.20	0.17	0.22	1.31
RSD _R (%)	8.4	5.3	11.8	10.9	7.6

Table A.17 — Erythrodiol content (mg/kg) by Reference Method (TLC)

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	1	1	1	1	1
mean (mg/kg)	31	61	17	52	598
r	2.8	4.4	1.5	4.0	71.0
S _r	1.0	1.6	0.5	1.4	25.3
RSD _r (%)	3.3	2.6	3.1	2.7	4.2
R	6.0	21.0	10.2	9.4	148.3
S _R	2.1	2.6	3.6	3.3	53.0
RSD _R (%)	7.0	12.4	20.8	6.5	8.9

Table A.18 — Uvaol content (mg/kg) by Reference Method (TLC)

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	2	1	1	1	2
mean (mg/kg)	3.0	8	4	20	65
r	0.83	1.5	3.3	3.5	12.5
S _r	0.30	0.55	1.2	1.2	4.5
RSD _r (%)	10.1	6.8	27.8	6.2	6.8
R	4.6	9.0	4.1	3.5	23.1
S _R	1.6	3.2	1.5	1.2	8.3
RSD _R (%)	55.6	40.0	34.0	6.2	12.7

Table A.19 — Erythrodiol content (mg/kg) by HPLC

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	1	1	0	0	1
mean (mg/kg)	32	60	18	51	605
r	3.0	8.8	2.5	5.6	36.5
S _r	1.1	3.1	0.9	2.0	13.0
RSD _r (%)	3.3	5.2	5.1	4.0	2.2
R	7.3	23.1	5.6	5.8	152.5
S _R	2.6	8.2	2.0	2.0	54.5
RSD _R (%)	8.1	13.7	11.4	4.1	9.0

Table A.20 — Uvaol content (mg/kg) by HPLC

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	0	1	1	0	1
mean (mg/kg)	5	8	5	20.0	65
r	1.6	1.3	0.80	2.8	6.5
S _r	0.55	0.48	0.29	1.0	2.3
RSD _r (%)	10.2	5.7	5.7	5.2	3.6
R	4.2	6.8	3.4	3.5	15.5
S _R	1.5	2.4	1.2	1.3	5.5
RSD _R (%)	27.3	28.6	24.0	6.4	8.5

Table A.21 — Aliphatic alcohols content (mg/kg) by Reference Method (TLC)

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	0	1	0	0	0
mean (mg/kg)	143	420	62	78	1512
r	5.5	23	4.5	5.1	70
S _r	1.9	8.2	1.6	1.8	24.9
RSD _r (%)	1.4	2.0	2.6	2.3	1.7
R	25	67	10	10	95
S _R	8.9	23.8	3.7	3.6	34.7
RSD _R (%)	6.2	5.7	6.1	4.7	2.3

Table A.22 — Aliphatic alcohols content (mg/kg) by HPLC

Sample	A	B	C	D	E
n	14	14	14	14	14
outliers	0	0	0	0	1
mean (mg/kg)	139	423	62	78	1495
r	6.9	15	6.2	5.9	46
S _r	2.5	5.3	2.2	2.1	16.2
RSD _r (%)	1.8	1.3	3.6	2.7	1.1
R	23	36	9.0	11	86
S _R	8.4	12.9	3.2	3.8	30.8
RSD _R (%)	6.0	3.1	5.2	4.9	2.1

2. Analysis of the collaborative test results for triterpenic dialcohols content:

Results of interlaboratory test to separate the unsaponifiable fraction by TLC of the triterpenic dialcohols fraction. Evaluation of the % and absolute content of erythrodiol and uvaol. An interlaboratory test was carried out in 2016 in accordance with ISO 5725. The results are summarised in Tables B.1 to B.6 for each parameter studied:

n	number of laboratories which participated in the test
outliers	number of laboratories with outlying values
mean	mean of the accepted results
r	repeatability
S_r	repeatability standard deviation
RSD_r(%)	repeatability coefficient of variation ($S_r \times 100 / \text{mean}$)
R	reproducibility
S_R	reproducibility standard deviation
RSD_R(%)	reproducibility coefficient of variation ($S_R \times 100 / \text{mean}$)

A: Lampante olive oil

B: refined olive oil (from sample 1)

C: Desterolysed high oleic sunflower oil + 3,13% / 49,26 mg/kg of standard erythrodiol

D: Pomace Olive oil (traded) same as D

E: Pomace Olive oil (traded) same as E

Table B.1 Erythrodiol + uvaol (% total sterols) by Reference Method (TLC)

Sample	A	B	C	D	E
n	17	17	17	17	17
outliers	1	3	3	2	3
mean (%)	3.3	4.3	3.5	22.8	22.7
r	0.3	0.7	0.2	1.5	1.5
S_r	0.1	0.2	0.1	0.5	0.5
RSD_r(%)	3.1	5.7	2.3	2.3	2.4
R	2.6	1.1	0.7	3.0	3.3
S_R	0.9	0.4	0.2	1.1	1.2
RSD_R(%)	28.5	9.0	7.0	4.7	5.1

Table B.2 Erythrodiol + uvaol content (mg/kg) by Reference Method (TLC)

	A	B	C	D	E
n	16	16	17	16	16
outliers	3	4	3	2	3
mean (mg/kg)	59	50	52	772	745
r	6.5	6.7	4.7	40	100
S_r	2.3	2.4	1.7	14	36
RSD_r(%)	3.9	4.8	3.3	1.8	4.8
R	9.9	14	31	146	183
S_R	3.5	4.8	11	52	65
RSD_R(%)	6.0	9.8	21.5	6.8	8.8

Table B.3 Erythrodiol (% total sterols) by Reference Method (TLC)

	A	B	C	D	E
n	17	17	16	17	17
outliers	1	3	1	2	3
mean (%)	3.1	3.9	3.4	18.8	18.7
r	0.3	0.6	0.2	1.2	1.5
S_r	0.1	0.2	0.1	0.4	0.5
RSD_r(%)	3.1	5.3	2.4	2.3	2.9
R	0.8	1.0	0.6	2.8	2.8
S_R	0.3	0.4	0.2	1.0	1.0
RSD_R(%)	8.9	9.1	6.6	5.3	5.3

Table B.4: Erythrodiol content (mg/kg) by Reference Method (TLC)

	A	B	C	D	E
n	16	16	16	16	16
outliers	1	3	2	0	2
mean (mg/kg)	53	46	48	638	635
r	5.1	13	4.1	41	78
S_r	1.8	4.6	1.5	15	28
RSD_r(%)	3.4	9.9	3.1	2.3	4.4
R	13	16	12	125	130
S_R	4.7	5.7	4.1	45	46
RSD_R(%)	8.8	12.2	8.6	7.0	7.3

Table B.5 Uvaol (% total sterols) by Reference Method (TLC)

	A	B	C	D	E
n	16	16	16	16	16
outliers	1	1	3	1	0
mean (%)	0.4	0.4	0.1	4.0	4.1
r	0.1	0.3	0.1	0.4	0.3
S_r	0.0	0.1	0.0	0.1	0.1
RSD_r(%)	11.4	23.3	35.8	3.4	2.4
R	0.7	0.2	0.1	0.6	0.7
S_R	0.2	0.1	0.0	0.2	0.3
RSD_R(%)	55.4	22.5	86.9	5.5	6.2

Table B.6 Uvaol content (mg/kg) by Reference Method (TLC)

	A	B	C	D	E
n	15	14	15	14	13
outliers	2	1	3	0	1
mean (mg/kg)	7.6	4.6	0.8	136	138
r	2.5	2.6	1.0	12	22
S_r	0.9	0.9	0.3	4.4	8.0
RSD_r(%)	11.6	20.0	43.3	3.2	5.8
R	11	3.3	2.2	31	36
S_R	3.9	1.2	0.8	11.0	12.8
RSD_R(%)	51.6	25.8	99.0	8.1	9.2