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Phenolic compounds and fatty acids content of some West Algerian olive oils

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Abstract

Olive represents the most widespread fruit cultivated in Algeria. Olive oil is the primary source of added fat in the Mediterranean diet with health benefits of which have been verified for millennia. Interest in phenolic compounds in olive oil has increased due to its antioxidant activity, which plays a very important role in human health. The present study is carried out to study the phenolic compounds and fatty acids profile of some olive oils from western Algeria. The quality parameters (acidity, peroxide value, K_{232}, K_{270}), tocopherol analysis, fatty acid composition and phenolic profile were determined by High performance chromatography (HPLC). The results showed that chemlal oil (SBA) recorded the highest level of tocopherol-a with 228.12 mg/Kg. Regarding the fatty acid composition, oleic acid was the most dominant, oil Oleaster (Bensekrane) records the highest percentage (72.80%) of oleic acid. The quantitative data on the phenolic content of the seven samples revealed that chemlal oil (SBA) had the highest level of polyphenols (328.99 mg/Kg). However, Sigoise oil (Sebra1) was characterized by the highest levels of tyrosol and hydroxytyrosol (15.89 mg/kg and 22.42 mg/kg, respectively). The highest concentrations of oleuropein derivatives and ligstroside derivatives were observed in chemlal oil (SBA) and the recoreded values were 105.97 mg/Kg and 83.49 mg/Kg, respectively. Chemlal oil (SBA) was characterized by the highest amount of lignans (35.93 mg/Kg), luteolin (10.16 mg/Kg) and apigenin (5.44 mg/Kg). Oleocanthal was found in all the tested samples and it was higher in Chemlal oil (102.43 mg/kg).

Keywords: antioxidants, fatty acids, HPLC, oleaster, olive oil, phenolic compounds

Introduction

Olive oil is one of the main components of the Mediterranean diet, known for its beneficial action on health. Olive oil is made up of around 99% fat and the remaining (1%) constitutes minor compounds mainly squalene, triterpene alcohols, sterols, phenols, and tocopherol derivatives. Each botanical species has its specific heritage in fatty acids (around fifteen in general) carried by triglycerides (Pouyet & Ollivier, 2014). Olive oil is considered one of the best sources of unsaturated fatty acid (mainly oleic acid). The chemical composition of virgin olive oil consists of monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), and saturated fatty acids (SFA) (Del Coco et al., 2013). MUFA was essentially attributed to decreased endothelial activation, and LDL susceptibility to oxidation (Dabbou et al., 2011). The role of polyphenols in inhibiting oxidation in virgin olive oils is well defined as primary antioxidants (El Yamani et al., 2019). Phenolic compounds are important in terms of virgin olive oil quality because of their contribution to the oil's flavor and aroma (Esalami et al., 2018). The most important phenolic compounds in virgin olive oil are phenolic acids, alcohols, secoiridoids, lignans and flavonoids. Among the sectors that have received financial and technical support is the olive growing in Algeria, which currently represents 4% of the beneficial agricultural area and 40% of the total arboreal area (Amrouni et al., 2017). There are two dominant varieties in the country namely, chemlal and sigoise. The objectives set for this sector is to reach an olive production of 8 million quintals an achievable target by 2019 knowing that the production in mid-season 2014/2015 reached 6505000 q, slightly exceeding the 2015 target of 6500000 q according to the data of Algerian Ministry of Agriculture and Rural Development. Olive oil production was the highest in the last fifteen years, reaching more than 900

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000 hl across the country and 25% above the campaign previously (ONFAA, 2016). In terms of olive oil production, Algeria is ranked eighth with 1.7% of world production (Semenuik, 2013). Several research studies have focused on determining the profile of phenolic compounds in virgin olive oil by various analytical techniques, including HPLC (Rovellini, 2008; Bubonja-Sonje et al., 2011). The lack of data on the olive oil of oranie, led us to undertake this work, which studies the profiles in phenolic compounds and fatty acids of some olive oils produced in the Algerian West.

Materials and Methods

Plant material

Two dominant varieties cultivated in western Algeria namely Sigoise and Chemlal and one wild variety namely Oleaster were selected for this study. Seven samples of olive were harvested by hand during the companion (2015-2016) in the regions of Zenata, Bordj Arima, Bensekrane, Sidi Belabbes, Sebra and Sig. The quantities of olive harvested were approximately 20 kg for each sample. Samples in summer harvested in December. The fruits are quickly transported in plastic crates for extraction.

The olive type Chemlal was collected from Zenata, Bordj Arima and Sidi Belabbes and was extracted by the continuous three-phase system, while Oleaster type was collected from Bensekrane and type Sigoise was collected from Sebra1, Sebra 2 and Sig and was extracted by the discontinuous system using super press. Oils were collected in smoked glass vials, filled, labeled and stored at 4 °C unti analysis. All the physico-chemical analyzes were carried out in the Fat and Derivatives Laboratory (Experimental stations for industry, Milan, Italy).

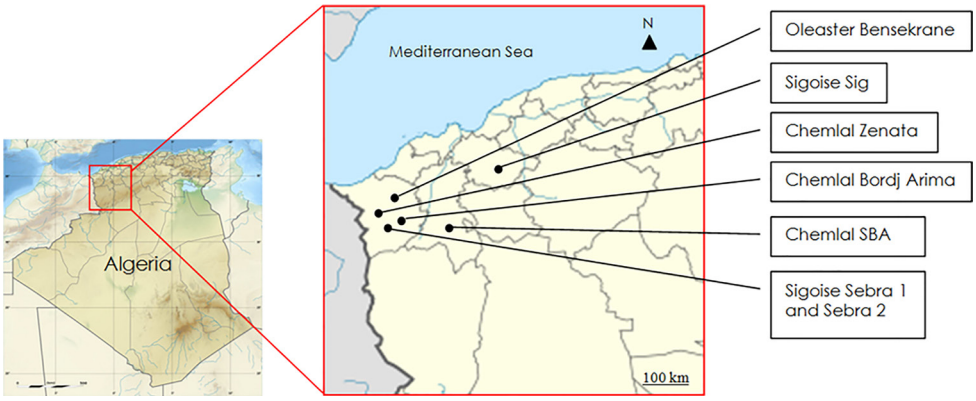

Figure 1. Location of the areas where the olives of the different samples were harvested.

Quality indices

Acidity and peroxide value were determined according to the protocols of U.I.C.P.A (1979). After dissolving 5 g of oil in 20 ml of a mixture of 95% diethyl ethanol and ethanol (V/V), the fatty acids present were titrated using 0.1 N potassium hydroxide solution in the presence of phenophthalein. A control test (without fat) was carried out under the same conditions.

The acidity was determined according to the following formula:

$$A\% \text{ (oleic acid)} = (V - V0) * (N * M / 10 * m)$$

V: volume in ml of KOH necessary to neutralize the sample; V0: volume in ml of KOH necessary to neutralize the blank; N: normality of potassium hydroxide; M: molar mass g / ml of oleic acid which is equal to 282g / ml; m: mass in grams of the test portion.

The peroxide value was evaluated as follows: 2 g of oil were dissolved in 10 ml of chloroform, 15 ml of glacial acetic acid and 1 ml of a saturated solution of potassium iodide were added. After reacting for 5 min in the dark, 75 ml of distilled water were added and the released iodine is titrated with a 0.01 N sodium thiosulfate solution in the presence of starch poisons as an indicator.

Peroxide value (PV) was determined according to the formula:

$$PV = N\ (V\text{-}V0) \times 1000/m \text{ (meq of } O_2/Kg)$$

Where

N: $Na_2S_2O_3$ normality; V, V0: volume in ml of $Na_2S_2O_3$ necessary for the titration of the sample and the blank test respectively; m: mass in grams of the test portion.

UV absorption at 232 nm and 270 nm were determined according to the International Olive Council method (IOC, 1996). After filtration of the oil samples through anhydrous sodium sulfate, a 1% solution of oil in hexane was prepared. Absorbance was measured at two wavelengths 232 nm and 270 nm. The extinction coefficients were expressed by the following equation:

$$E = A\lambda / C * l$$

Where
E: specific extinction at the wavelength λ; Aλ: absorbance at λ nm; C: concentration of the solution in g / 100 ml; l: thickness of the tank in centimeters.

Analysis of tocopherols

Tocopherols were evaluated according to the method developed by Rovellini et al. (1997). A solution of olive oil in acetone was analyzed by HPLC on reverse phase silica column (Allsphere ODS2 Alltech 5 µm, 250 mm . 4.6 mm) and was eluted with acetonitrile / methanol (1: (1)) Flow rate of 1.3 mL / min. UV detector was set at 292 nm.

Determination of the fatty acid composition

The methyl esters were prepared according to the E.C. method (2002). An aliquot of 0.5 g of oil was dissolved in 5 ml of hexane added 0.5 ml of a methanolic solution of potassium hydroxide (2 N) stirred for 30 seconds, then centrifuged at 3000 rpm for 5 minutes. Two drops of the supernatant were removed and mixed with 1 ml of hexane. A volume of 1µL of the hexane layer was injected into a gas chromatograph of Chrompack C 9002 type.

Determination of phenolic compounds by HPLC (IOC, 2017)

The method was based on direct extraction of the biophenolic minor polar compounds from olive oil by means of a methanol solution and subsequent quantification by HPLC with the aid of a UV detector at 280 nm. Syringic acid was used as the internal standard. The content of the natural and oxidised oleuropein and ligstroside derivatives, lignans, flavonoids and phenolic acids was expressed in mg/kg of tyrosol. A solution of internal standard (1 mL of 0.015 mg mL^{-1} of syringic acid in water/MeOH 20:80 v/v) was added to a sample of virgin olive oil (2 g). The mixture was shaken (30 s) and 5 mL of the extraction solution containing water and MeOH (20:80 v/v) was added. The obtained mixture was shaken for 1 min, extracted for 15 min in an ultrasonic bath and then centrifuged at 5000 rpm (2500 g) for 25 min at T = 20 °C. The upper phase was filtered using a 0.45 µm PVDF syringe filter, and then 20 µL of the filtered solution was analyzed by HPLC with a UV detector at 280 nm. The HPLC system consisted of a C18 Spherisorb ODS-2 reverse column (5 µm, 250mm× 4.6mm). Elution was performed at a flow rate of 1mL min^{-1} following a gradient composed of amixture of water and orthophosphoric acid (99.8:0.2 v/v) (solvent A), MeOH (solvent B) and acetonitrile (solvent C): from 96% (A)–2% (B)–2% (C) to 0% (A)–50% (B)–50% (C) in 60 min. The last gradient was kept for 10 min. The successive gradient was: from 0% (A)–50% (B)–50% (C) to 96% (A)–2% (B)–2% (C) in 2 min and then kept for 10 min. The identification of phenolic compounds was performed by HPLC–MS.

Biophenol content (hydroxytyrosol, tyrosol, natural and oxidised oleuropein and ligstroside derivatives, lignans, flavonoids and phenolic acids), expressed in mg/kg, is calculated by measuring the sum of the areas of the related chromatographic peaks according to the following formula, the result was expressed without decimal place.

$$(mg/kg) = \frac{(\Sigma A) \times 1000 \times RRF_{syr/tyr} \times (W\ syr.\ acid)}{(A\ syr.\ acid) \times (W)}$$

Where:
(ΣA): is the sum of the peak areas of the biophenols (hydroxytyrosol, tyrosol, natural
and oxidised oleuropein, ligstroside derivatives, lignans, flavonoids and phenolic acids) recorded at 280 nm;
A syr. acid: is the area of the syringic acid internal standard recorded at 280 nm;
1000: is the factor used to express the result in mg/kg;
W: is the weight of the oil used, in g;
$RRF_{syr/tyr}$: is the multiplication coefficient for expressing the final results as tyrosol;

W syr. acid: is the weight, in mg, of the syringic acid used as internal standard in 1 mL of solution added to the sample.

Results and discussion

Quality indices

Acidity is one of the main quality criteria. As shown in the (table. 1), the olive oils Chemlal fom Zenata, Bordj Arima and SBA recorded low acidity (0.6% to 0.8%) according to the IOC standard. So they are classified as extra virgin olive oils. The olive oils Sigoise from Sebra1, Sig and Oleaster from Bensekrane have acidity between 1.7% to 2% which classified them in the category of virgin olive oils. Sigoise oil from Sebra 2 displayed the highest acidity with 2.8% and is classified as common olive oil. Differences in acidity levels between olive oils can be related to the maturity of the olive. The oils studied herein are less acidic than the oils analyzed by Boulfane et al. (2015). On the other hand, our results are high compared to those reported by Laribi et al. (2011) and Laincer et al. (2014) on the oils of the center and the east of Algeria which noted an acidity lower than 0.8%.

Significant differences were found between Chemlal from Zenata, Bordj Arima, SBA and other oils. These differences can be explained by the degree of maturity of the olives and the influence of the cultivar. The high acidity of the Sigoise oil collected from Sebra 2 can be explained by the late harvest of fruits and extraction mode by press. The longer the storage time, the greater the free acidity in the fruit, which depreciates and degrades the organoleptic quality of the extraction product. At the mill level, the oils extraction and storage play an important role in reducing their quality. The most important modification that we encounter is the oxidation or rancidity that is caused by several factors, such as oxygen, light, temperature, factors that favor several phenomena in this case fermentation. Regarding the proxyde value, there are significant differences between the oils of Chemlal from SBA, Sigoise from Sebra1 and Sig and other oils. The oils analyzed show values that vary between 6.7 meq of O_2/kg for Chemlal oil from Zenata and 14.6 meq of O_2/kg for Sigoise oil from Sebra1. The values reached are lower than the COI commercial standard, (2003) (20 meq of O_2/Kg) of olive oils of category: Extra virgin, virgin and common. The oils analyzed present peroxide values close to the oils of eastern Algeria analyzed by Benrachou et al. (2010) between 7.86 and 11.40 meq of O_2/Kg and lower than certain Moroccan oils for which the peroxide value varies between 2.66 and 28.50 meq of O_2/Kg (Elbir et al., 2014). All the oils studied have relatively average levels of peroxide value, which indicates an average oxidation of the oil.

The specific extinctions of an olive oil at 232 and 270 nm reflect the oxidation state of the oil. The oxidation leads to the formation of the conjugated dienes which absorb at 232 nm, the secondary oxidation products have a maximum of absorbance around 270 nm. Average variations recorded between the oils Chemlal (SBA), Sigoise (Sebra1), Sigoise (Sig) and other oils for the coefficient K_{232} and between Oleaster (Bensekrane), Sigoise (Sebra 2) and Sig and other oils for K_{270}. The highest value of K_{232} is displayed by Chemlal Oil from SBA (2.42), while the lowest value is displayed by Chemlal Oil from Zenata (1.87). As for the coefficient K_{270}, the values were between 0.13 and 0.20. All oil samples have specific UV extinction coefficients (K_{232}, K_{270}) below the IOC (2003) limits for virgin, virgin and common olive oil. Our results are similar to those recorded by Laincer et al. (2014), for the oils of eastern Algeria which vary between 1.15 and 2.46 for K_{232} and between 0.10 and 0.20 for K_{270}. The analysis results (acidity, peroxide value and specific extinction coefficients in the UV (K_{232}, K_{270}) performed on the different oils studied all fit perfectly within the limits defined by the IOC (2003). which dismisses the high acidity values of Sigoise from Sebra1, Sebra 2, Sig and Oleaster from Bensekrane.

Several factors may explain these results. This is the late harvest of olives, excessive exposure of olives and oil extracted with oxygen from the air and light, see also a warming of the dough during the crushing (Tanouti et al., 2011). The specific extinction at 232 nm and 270 nm of oil reflects its oxidation state. The higher its extinction at 232 nm, the more it is peroxidized.

Analysis of tocopherols

Table 1. The quality indices of different olive oils.

Olive oils	A %	PV	K_{232}	K_{270}
Chemlal Zenata	0.60 ± 0.01	6.70 ± 0.02	1.873 ± 0.02	0.137 ± 0.00
Chemlal Bordj arima	0.80 ± 0.00	7.80 ± 0.01	1.887 ± 0.00	0.14 ± 0.00
Oleaster Bensekrane	2.00 ± 0.01	8.40 ± 0.05	1.90 ± 0.00	0.201 ± 0.00
Chemlal (SBA)	0.60 ± 0.00	11.80 ± 0.02	2.429 ± 0.00	0.17 ± 0.00
Sigoise Sebra 1	1.70 ± 0.00	14.60 ± 0.15	2.07 ± 0.01	0.168 ± 0.00
Sigoise Sebra 2	2.80 ± 0.01	6.60 ± 0.1	1.991 ± 0.00	0.201 ± 0.00
Sigoise Sig	2.00 ± 0.00	11.7 ± 0.2	2.086 ± 0.00	0.207 ± 0.00

A%: acidity, PV: peroxide value

The seven oils studied have a fairly high percentage of tocopherol-a (Table 2), the highest level being found in Chemlal oil from SBA with 228.12 mg/kg, followed by Sigoise oil from Sebra 2 and Oleaster from Bensekrane with 202.9 and 201.71 mg/Kg respectively. While the oils Chemlal from Bordj Arima, Zenata and Sigoise from Sig showed levels of 193.55, 179.72 and 156.36 mg/kg respectively. However, Sigoise oil from Sebra1 recorded the small value of 108.77 mg/Kg.

The highest content of tocopherol-γ was found in Oleaster oil from Bensekrane with 11.33 mg/kg. The lowest levels were recorded by the oils of Sigoise from Sig, Sebra1 and Chemlal from Bordj Arima with 5.8, 5.86 and 6.58 mg/kg, respectively. As for oils Chemlal from SBA, Sigoise from Sebra 2 and Chemlal from Zenata; They have intermediate values of 9.29, 8.86 and 7.11 mg/kg, respectively. For tocopherol-β, Sigoise oil from Sebra 2 and Chemlal oil from SBA have the highest values with 3.16 and 2.11 mg/kg, respectively. The lowest rate was recorded by Chemlal oil from Zenata with 1.18 mg/kg.

The highest value of tocopherol-δ was determined in Sigoise oil from Sebra 2 with 0.69 mg/kg and the lowest value was recorded by Sigoise oil from Sebra 1 with 0.35 mg/kg, for the others oils the values vary between 0.49 and 0.58 mg/Kg. The total content of tocopherols showed the same tendency of tocopherol-a, because it was the most representative in the composition of tocopherols. Minimum and maximum levels (240.1 and 116.35 mg/kg) were observed respectively in the oils Chemlal from SBA and Sigoise from Sebra 1, respectively.

Table 2. Tocopherol content (mg/kg) of different olive oils.

Olive oils	Tocopherol-δ	Tocopherol-γ	Tocopherol-β	Tocopherol-a	Tocopherol Total
Chemlal Zenata	0.56	7.11	1.18	179.72	188.55
Chemlal Bordj arima	0.57	6.58	1.65	193.55	202.35
Oleaster Bensekrane	0.49	11.33	1.98	201.71	215.49
Chemlal (SBA)	0.58	9.29	2.11	228.12	240.1
Sigoise Sebra 1	0.35	5.86	1.37	108.77	116.35
Sigoise Sebra 2	0.69	8.86	3.16	202.9	215.6
Sigoise Sig	0.51	5.8	1.69	156.36	164.5

These results are in agreement with several studies which indicated that the tocopherol content is very dependent on the variety (Manai-Djebali et al., 2012 ; Dağdelen et al., 2012). According to Alasalvar et al. (2003), the proportion of tocopherols is a function of several factors such as the nature of the oil, geographical origin, culture and climate. Our results are close to those obtained by Tamendjari et al., (2018) on the chemlal and oleaster variety of the Bejaia region which are between 192 and 335 mg/kg.

Fatty acid composition

The analysis of the fatty acid composition (Table 3) is qualitatively similar between the samples. Quantitatively, all the oils studied have different levels of fatty acids that meet the standards set by IOC (2003).

Table 3. Fatty acid compositions (%) of the different oils.

Fatty acids	Chemlal Zenata	Chemlal Bordj Arima	Oleaster Bensekrane	Chemlal (SBA)	Sigoise Sebra 1	Sigoise Sebra 2	Sigoise Sig
C14 : 0	0.02	0.02	0.02	0.02	0.03	0.03	0.04
C16 : 0	12.81	12.09	11.55	15.86	11.30	14.54	11.40
C17 : 0	0.05	0.04	0.04	0.04	0.04	0.05	0.06
C18 : 0	2.58	2.80	2.51	2.29	2.83	2.95	3.96
C20 : 0	0.34	0.36	0.32	0.34	0.32	0.35	0.37
C22 : 0	0.09	0.09	0.08	0.06	0.08	0.11	0.09
C24 : 0	0.04	0.04	0.04	0.04	0.04	0.05	0.04
SFA	15.93	15.44	14.56	18.65	14.64	18.08	15.96
C16 : 1	1.41	1.21	1.16	2.11	1.01	1.76	0.96
C17 : 1	0.08	0.06	0.07	0.09	0.06	0.08	0.08
C18 : 1	70.31	70.41	72.80	67.78	72.26	68.04	69.44
C20 : 1	0.28	0.30	0.28	0.25	0.31	0.28	0.31
MUFA	72.08	71.98	74.31	70.23	73.64	70.16	70.79
C18 : 2	11.21	11.66	10.24	10.34	10.86	10.96	12.23
C18 : 3	0.81	0.87	0.93	0.75	0.88	0.82	1.0
PUFA	12.02	12.53	11.17	11.09	11.74	11.78	13.3
C18 : 1/C18 : 2	6.27	6.03	7.1	6.55	6.65	6.2	5.67

C14: 0: Myristic acid, C16: 0: Palmitic acid, C16: 1: Palmitoleic acid C17: O: Heptadecanoic acid, C17: 1: Heptadecenoic acid, C18: O: Stearic acid, C18: 1: Oleic acid, C18: 2: linoleic acid, C18: 3: linolenic acid, C20: 0: arachidic acid, C20: 1: gadoleic acid, C22: 0: Behenic acid, C24: 0: lignoceric acid, MUFA: monounsaturated fatty acids, SFA: saturated fatty acids. PUFA: polyunsaturated fatty acids.

Oleic acid (C18: 1) is the dominant fatty acid was found in all the oils studied with proportions greater than 60%. The highest values recorded for Oleaster from Bensekrane, Sigoise from Sebra1, Chemlal from Bordj Arima and Chemlal from Zenata oils were 72.80%, 72.26%, 70.41% and 70.31%, respectively followed by the other oils; however the lowest value being noted for Chemlal Oil from SBA wich recorded 67.78%.

The percentages of oleic acid in the olive oils studied are similar to the values found by Abu-Reidah et al. (2013) Who found values ranging from 67.24 to 72.27% for Palestinian oils. However, they are a bit higher than the values reported by Issaoui et al. (2010) for Tunisian oils (54.6 to 66.8%).

The fatty acid content of olive oil varies depending on the production area, latitude, climate, variety and stage of ripening of the fruit. According to Benlemlih & Ghanam. (2012) Moroccan and Tunisian oils are rich in

linoleic and palmitic acids and lower in oleic acid.

The percentages of linoleic acid (C18: 2) vary was 10.24% for Oleaster oil from Bensekrane and 12.23% for Sigoise from Sig. While the levels of palmitic (C16: 0) and stearic (C18: 0) acid vary between 11.30% for Sigoise oil from Sebra1 15.86% for Chemlal from SBA 2.29% for Chemlal oil from SBA and 3.96% for Sigoise from Sig, respectively. Oleaster oil from Bensekrane has the highest oleic acid / linoleic acid ratio (7.1) and the lowest remains for Sigoise oil from Sig (5.67). Our results are superior to that reported by Djelili-Mamou et al. (2018) on the olive oils of the Chemlal and Azeradj varieties from the Bejaia regions (Northern Algeria) which have recorded values between 3.50-4.46.

The levels of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) vary depending on the oils and the variety; the oils Chemlal from SBA and Sigoise from Sebra 2 have a percentage of acids, Saturated fats of 18.65% and 18.08%, respectively, monounsaturated fatty acids of 70.23% and 70.16% and polyunsaturated fatty acids of 11.09% and 11.78%. While the Sigoise from Sig, Chemlal from Zenata, Chemlal from Bordj Arima, Sigoise from Sebra1 and Oleaster from Bensekrane oils record a total of saturated fatty acids of 15.96, 15.93, 15.44, 14.64 and 14.56% respectively, monounsaturated fatty acids of 70.79, 72.08, 71.98, 73.64 and 74.31% and polyunsaturated fatty acids of 13.3, 12.02, 12.53, 11.74 and 11.17%. For the different oils tested, respectively. Regarding of ratio oleic acid / linoleic acid (C18: 1 / C18: 2), the olive oils studied have high ratios between 5.67 for Sigoise oil from Sig and 7.1 for Oleaster oil from Bensekrane. The results of Sönmez et al. (2018) have shown that the composition of olive oil varies considerably during maturation. With a delayed harvest, the content of free fatty acids increases and the MUFA/PUFA ratio decreases. The fatty acid composition of the olive is an important parameter in the shelf life which is quantitatively affected by the main factor such as the variety of the olive used in the production of the oil. The most studied aspects include the cultivar and the origin, the ripening of the fruit, the period of harvest and the pedoclimatic conditions of the production.

Phenolic compound compostion (mg/Kg) of the different oils

Five main phenolic groups were detected, phenolic alcohols (hydroxytyrosol and tyrosol), secoiridoids (mainly derived from oleuropein and ligstroside and elenolic acid), lignans, flavonoids (luteolin and apigenin) and phenolic acids.

Total biophenols

The Total biophenols contents range from 93.32 mg/kg for Sigoise oil from Sig and 328.99 mg/kg for Chemlal oil from SBA, where as Chemlal from Zenata, Sigoise from Sebra1 and Chemlal from Bordj Arima display values of 2.16.64, 191.3 and 188.49 mg/kg respectively. Sigoise from Sebra 2 and Oleaster from Bensekrane oils have rates of 169.56 and 141.68 mg/kg. These results can be explained by the degree of maturity of the olives harvested, the difference in the variety, the extraction system of the oils and the geographical origin. It is well known that the content of phenolic compounds is not only related to variety; however, it is the result of a complex interaction between several factors, namely the maturity index of olives, the season, the region, climatic conditions, the health status of olives (Tamendjari et al., 2004), the oil extraction system, extraction conditions (Vekiari and Koutsaftakis, 2002), the influence of genotyping and other agro-climatic parameters (Ragusa et al., 2017). The significant difference noticed between the polyphenol contents of the oils Chemlal from SBA, Zenata and Bordj Arima, is explained by the difference of the region of production of the olives.

Other research has shown that the profile of phenolic compounds is also affected by the geographical origin of the olive oil variety (Essiari et al., 2014; Arslan et al., 2013). Issaoui et al. (2010) worked on two Tunisian varieties Chemlali and Chetoui in two different regions; North and South of Tunisia, they noted: the effect of the geographical area of cultivation on the total phenols, the cultures of the North produced oils with a higher content of total phenols in comparison with the oils originating from the South of Tunisia and the cultures of the North had the highest concentration. High in o-diphenols; hence higher altitude varieties produced larger amounts of phenols than those grown at a lower altitude.

The Sigoise from Sebra1, Sebra 2 and Oleaster from Bensekrane oils have low polyphenol contents compared to the oils of the Chemlal varieties, despite the work of Bengana et al. (2013) on olive oils from the variety Chemlal of North-Central Algeria, it has been shown that the presence of polyphenols is naturally very low in the variety Chemlal, this result is certainly in the advanced degree of maturity of the olive and the extraction system. The oils studied have polyphenol contents higher than the contents of the Spanish varieties analyzed by Ceci & Carelli (2007), which have total polyphenol contents of between 37.2 and 93.2 mg/kg, and the varieties Picual, Barnea, Empeltre, Manzanilla Californiana and Manzanilla Criolla grown in Argentina, with contents ranging from 25.3 to

92.7 mg/kg. From our results, it appears that the cultivar is an important factor influencing the total polyphenol quantitative composition of olive oil.

In another study, Taticchi et al. (2013) noted the presence of a positive relationship between the kneading temperature (20°C, 25°C and 35°C) and the concentration of phenolic compounds, Indeed, the olive oil obtained from a continuous system Traditional three-phase centrifugation extraction is depleted in polyphenols compared to the continuous two-phase centrifuge extraction system.

Phenolic alcohol

The phenolic alcohols quantity varies between 38.31 mg/kg for Sigoise oil from Sebra1 and 7.01 mg/kg for oleaster from Bensekrane. Hydroxytyrosol (3,4-DHPEA) and tyrosol (p-HPEA) are the main phenolic alcohols present in the oils studied, which is in agreement with the results obtained by (Romero et al., 2015).

The values range from 4.99 for Sigoise oil from Sig to 15.89 mg/kg for Sigoise oil Sebra1 tyrosol, and between 1.07 for Oleaster oil from Bensekrane and 22.42 mg/kg for Sigoise oil from Sebra1 of hydroxytyrosol. All of the oils studied have higher tyrosol contents than those of hydroxytyrosol except the oils Chemlal from Zenata 12.32 mg/kg and Sigoise from Sebra1 22.42 mg/kg of hydroxytyrosol (Table 4). These high values are not unique for olive oils, in fact Gilbert-López et al. (2014) found that hydroxytyrosol concentration values are more than 50 mg/kg in seventy eight samples of extra virgin olive oil collected from ten different countries.

Table 4. Content of phenolic compounds (mg/kg) of olive oils by HPLC.

Olive oils	Hydroxy tyrosol	Tyrosol	Oleuropein	Derivatives of Oleuropein	Derivatives of Ligstroside	Oleo canthal	Total secoiridoid Acids	Decarboxymethylelenolic acid	Elenolic acid
Chemlal Zenata	12.32	9.17	0.16	89.6	79.13	42.76	39.18	10.39	28.79
Chemlal Bordj arima	3.75	9.48	0.11	60.08	83.49	40.93	49.72	7.72	42
Oleaster Bensekrane	1.07	5.94	0.24	34.37	54.97	24.43	18.29	2.74	15.55
Chemlal (SBA)	2.51	6.44	0.06	105.97	147.56	102.43	24.93	2.63	22,3
Sigoise Sebra 1	22.42	15.89	0.77	87.48	64.66	23.69	30.19	6.48	23.71
Sigoise Sebra 2	5.28	9.68	1.66	48.6	44.78	13.26	22.68	5.82	16.86
Sigoise Sig	2.47	4.99	1.11	32.85	41.43	14.03	6.8	1.56	5.24

Derivatives of secoiridoids

Oleuropein and ligstroside were the most abundant group of phenolic compounds in all analyzed samples (Table 4), regardless of their geographical origin and variety. As reported by Lauri et al. (2013), these compounds are largely associated with the sensory properties of olive oils because they are the main sources of bitterness and spiciness. In our case, the highest concentrations of oleuropein derivatives were observed in Chemlal oil from SBA with 105.97 mg/Kg followed by Chemlal oil from Zenata, Sigoise oil from Sebra1 and Chemlal oil from Bordj Arima with 89.6, 87.48 and 60.08 mg/kg, respectively. While the lowest concentration is recorded by Sigoise oil from Sig with 32.85 mg/kg. As for ligstroside derivatives, Sigoise from Sig, Sebra 2 and Oleaster from Bensekrane oils have the lowest values 41.43, 44.78 and 54.97 mg/kg, respectively. While the highest value remains for Chemlal Oil from SBA in a row come the oils Chemlal from Bordj Arima, Zenata and Sigoise from Sebra1 with 83.49, 79.13 and 64.66 mg/kg, respectively. Our results are lower than that found by Mansouri et al. (2016) on the varieties Arbequina, Arbosana, Koroneiki and Moroccan Picholine which are between (26.35-146.72 mg/Kg) for oleuropein derivatives and 75.41-165.56 mg/Kg derivatives of ligstrosides.

Sigoise from Sebra 2 and Sig oils have high levels of oleuropein, which are 1.66 and 1.11 mg/kg, respectively. While other oils have low values between 0.06 and 0.77 mg/kg. Oleuropein and its aglycone form decrease with the progression of ripening (Caponio et al., 2001), as well as decarboxymethyl oleuropein aglycone (Bengana et al., 2013).

The elenolic acid content varies between 5 mg/kg for Sigoise oil from Sig and 42 mg/kg for Chemlal oil from Bordj Arima. In addition, another secoiridoid acid, namely decarboxymethylelenolic acid, ranging from 1.56 mg/kg for Sigoise oil from Sig to 10.39 mg/kg for Chemlal oil from Zenata.

Freshly pressed extra virgin olive oils also contain aglycone (-) - decarboxymethyl ligstroside, also known as oleocanthal. Oleocanthal has been shown to mimic the pharmacology of ibuprofen (Cicerale et al., 2012). The concentration of oleocanthal in extra virgin olive oils is highly variable, ranging from

0.2 mg/kg to 498 mg/kg (Gómez-Rico et al., 2006). Beauchamp et al. (2005) demonstrated that extra virgin olive oils produced in different countries had variable oleocanthal concentrations. For example, extra virgin olive oil produced in the United States contained a low concentration of oleocanthal (22.6 mg/kg), while extra virgin olive oil produced in Italy contained very high levels of this compound (up to 191.8 mg/kg). The seven samples studied contained oleocanthal, found a considerable amount in Chemlal Oil from SBA 102.43 mg/Kg the lowest values were recorded by Sigoise oils from Sebra 2 and Sig 13.26 mg/kg and 14.03 mg/kg, respectively.

Quantity of lignans

The oil samples vary between 6.48 mg/kg for Sigoise oil from Sig and 35.93 mg/kg for Chemlal oil from SBA followed by sigoise oils from Sebra1, Chemlal from Bordj Arima and Chemlal from Zenata with grades of 25.91, 25.39 and 24.97 mg/kg respectively, remainder Sigoise oil from Sebra 2 with 20.06 mg/kg and Oleaster oil from Bensekrane with 17.65 mg/kg (Table 5).

Table 5. Content of phenolic compounds (mg/kg) of olive oils by HPLC.

Olive oils	Total Lignans	Total Phenolic Acids	Total Flavonoids	Luteolin	Apigenin	Total Biophenols	Total Natural Biophenoles	Total Aromatic Alcohols
Chemlal Zenata	24.97	2.2	8.44	5.69	2.75	216.64	204.33	21.49
Chemlal Bordj arima	25.39	3.53	6.97	4.94	2.03	188.49	179.45	13.23
Oleaster Bensekrane	17.65	4.35	13.33	9.53	3.8	141.68	124.67	7.01
Chemlal (SBA)	35.93	3.35	15.6	10.16	5.44	328.99	308.4	8.95
Sigoise Sebra 1	20.06	3.45	4.86	3.14	1.72	191.3	180.49	38.31
Sigoise Sebra 2	25.91	16.97	11.58	7.05	4.53	169.56	147.85	14.95
Sigoise Sig	6.48	2.12	3.91	2.45	1.46	93.32	86.77	7.46

Lignans are not indicative of the variety, but rather of the process used to obtain olive oil (Laincer et al., 2016). Our results are inferior to those obtained by Brenes et al. (2002) whose contents are higher than 100 mg/kg, but higher than the contents of the varieties Picual and Hojiblanca analyzed by García-Villalba et al. (2010).

Flavonoids

Flavonoides were found in the range of 3.91 to 15.6 mg/kg detected respectively in Sigoise from Sig and Chemlal from SBA oils. Luteolin and apigenin were the compounds relevant in this group (Table 5). Luteolin, the most abundant flavonoid in the analyzed samples, ranged from 2.45 mg/kg for Sigoise oil from Sig to 10.16 mg/kg for Chemlal oil from SBA, while apigenin concentrations ranged from 1.46 mg/kg for Sigoise oil from Sig and 5.44 mg/kg for Chemlal oil from SBA. Our results are inferior to those obtained by Ilyasoglu et al. (2010) and Andjelkovic et al. (2009). Luteolin and apigenine belong to the class of flavones, they are derivatives of 7-luteolin glucoside and apigenin glucoside respectively present in the olive fruit.

Phenolic acids

Phenolic acids have already been associated with the color and sensory qualities and antioxidant properties of health-related foods (Cartoni et al., 2000). The oils studied showed amounts of phenolic acids which vary between 2.12 mg/kg for Sigoise oil from Sig and 4.35 mg/kg for Oleaster oil from Bensekrane, except the Sigoise oil from Sebra 2 which recorded an acceptable quantity of 16.97 mg/kg (Table 5).

Conclusions

In this study, our objective was to develop certain olive oils from the olive heritage of Western Algeria through the study of their phenolic compounds and the fatty acid profile. The seven samples studied showed an interesting quality in terms of phenolic compounds and fatty acids and they provided a lot of information on the quality of olive oils from Western Algeria. The qualitative composition of the seven oils studied is similar to individual phenolic compounds, but quantitatively different, which allowed us to distinguish between the oils; Chemlal oil from SBA is distinguished from other varieties by the highest polyphenol contents (328.99 mg/Kg), followed by Chemlal oil from Zenata with (216.64 mg/Kg). The tocopherol composition has a fairly high percentage of tocopherol-a, the highest rate is displayed by Chemlal oil from SBA with (228.12 mg/Kg). The analysis of the composition of fatty acids is qualitatively similar between the samples. Quantitatively, all the oils studied have contents of different fatty acids meeting the standards established by the International Olive Oil Council. Oleic acid (C18: 1) is the dominant fatty acid, all the oils studied have proportions greater than 60%. The highest value is recorded by Oleaster oil from Bensekrane with 72.80%.

From all the results obtained, it appears that the cultivar is an important factor which influences the phenolic and fatty acid composition of different olive oils, the difference in the region of production of the olives can also influence these compositions.

References

Abu-Reidah, I.M., Yasin, M., Urbani, S., Servili, M., Montedoro, G. 2013. Study and characterization of Palestinian monovarietal Nabali virgin olive oils from northern West Bank of Palestine. *Journal Food Research International* 54: 1959-1964.

Alasalvar, C., Shahidi, F., Ohshima, T., Wanasundara, U., Yurttas, H.C., Liyanapathirana, C.M., Rodrigues, F.B. 2003. Turkish Tombul Hazelnut. 2. Lipid characteristics and oxidative stability. *Journal of Agricultural and Food Chemistry* 51: 3797-3805.

Amrouni Sais, H., Fethallah, R., Fahas, M. 2017. Les performances techniques et économiques de la filière de l'huile d'olive en Algérie. *Le secteur oléicole contraintes, enjeux et défis* 35.

Andjelkovic, M., Acun, S., Van Hoed, V., Verhe, R., Van Camp, J. 2009. Chemical composition of Turkish olive oil-Ayvalik. *Journal of the American Oil Chemists' Society* 86: 135-140.

Arslan, D., Karabekir, Y., Schreiner, M. 2013. Variation of phenolic compounds, fatty acids and some qualitative characteristics of *Sariulak* olive oil as induced by growing area. *Food Research International* 54: 1897-1906.

Beauchamp, G.K., Keast, R.S.J., Morel, D., Lin, J., Pika, J., Han, Q., Lee, C.H., Smith, A.B., Breslin, P.A.S. 2005. Ibuprofen-like activity in extra-virgin olive oil. *Nature* 437: 45-46.

Bengana, M., Bahouche, A., Lozano-Sánchez, J., Amir, Y., Youyou, A., Segura-Carretero, A., Fernández-Gutiérrez, A. 2013. Influence of olive ripeness on chemical properties and phenolic composition of *Chemlal* extra-virgin olive oil. *Food Research International* 54: 1868-1875.

Benlemlih, M, Ghanam, J. 2012. *Polyphénols d'huile d'olive, trésors santé ! Étude scientifique*. Macro pietteur, Belgique. 208 p.

Benrachou, N., Henchiri, C., Djeghaba, Z. 2010. Caractérisation de trois huiles d'olive issues de trois cultivars de l'Est algérien. *African Journals Online* 22: 12-22.

Boulfane, S., Maata, N., Anouar, A., Hilali, S. 2015. Caractérisation physicochimique des huiles d'olive produites dans les huileries traditionnelles de la région de la Chaouia-Maroc. *Journal of Applied Biosciences* 87: 8022-8029.

Brenes, M., Garcıa, A., Rios, J.J., Garcıa, P., Garrido, A. 2002. Use of 1 acetoxypinoresinol to authenticate *Picual* olive oils. *International Journal of Food Science and Technology* 37: 615-625.

Bubonja-Sonje, A., Giacometti, J., Abram, M. 2011. Antioxidant and antilisterial activity of olive oil, cocoa and rosemary extract polyphenols. *Food Chemistry* 127: 1821-827.

Caponio, F., Gomes, T., Pasqualone, A. 2001. Phenolic compounds in virgin olive oils: influence of the degree of olive ripeness on organoleptic characteristics and shelf-life. *European Food Research and Technology* 212: 329-333.

Cartoni, G.P., Coccioli, F., Jasionowska, R., Ramires, D. 2000. HPLC analysis of the benzoic and cinnamic acids in edible vegetable oils. *Italian Journal of Food Science* 12: 163-173.

Ceci, L.N., Carelli, A.A. 2007. Characterization of monovarietal Argentinian olive oils from new productive zones. *Journal of American Oil Chemist's Society* 84: 1125-1136.

Cicerale, S., Lucas, L., Keast, R.S. 2012. Antimicrobial, antioxidant and antiinflammatory phenolic activities in extra virgin olive oil. *Current Opinion in Biotechnology* 23: 129-135.

Dabbou, S., Brahmi, F., Dabbou, S., Issaoui, M., Sifi, S., Hammami, M. 2011. Antioxidant capacity of Tunisian virgin olive oils from different olive cultivars. *African Journal Food Science and Technology* 2: 92-97.

Dağdelen, A., Tümen, G., Ozcan, M.M., Dündar, E. 2012. Determination of tocopherol contents of some olive varieties harvested at different ripening periods. *Natural Product Research* 26: 1454-1457.

Del Coco, L., Perri, E., Cesari, G., Muzzalupo, I., Zelasco, S., Simeone, V., Schena, F.P., Fanizzi, F.P. 2013. NMR-based metabolomic approach for EVOO from secular olive trees of Apulia region. *European Journal of Lipid Science Technology* 115**:** 1043–1052.

Djelili-Mamou, F., Servili, M., Proietti, P., Djoudad-Kadji, H., Tamendjari, A. 2018. Physicochemical characteristics and sensorial profile of two Algerian varietal virgin olive oils (*Chemlal and Azeradj*) and their blends. *La Rivista Italiana delle Sostanze Grasse* 95: 5-16.

E.C. 2002. *Regulation n° 796 of 6 May 2006 on changes EC- Regulation. 2568/91*. Official J.L.128/815/05/02. 2002. Bruxelles, Belgium.

El Yamani, M., Sakar Mansouri, E.H., Serghini-Caid, H., Elamrani, A., Rharrabti, Y. 2019. Effect of pigments and total phenols on oxidative stability of monovarietal virgin olive oil produced in Morocco. *La Rivista Italiana delle Sostanze Grasse* 96: 17-24.

Elbir, M., Amhoud, A., Houlali, I., Moubarik, A., Hasib, H., Jouad, A., Mbarki, M. 2014. Characterization and classification of monocultivar olive oils from two areas in Morocco (Meknes-Tafilalet and Marrakech-Tansift-Al Haouz). *Journal of Materials and Environmental Science* 5: 565-570.

Esalami, S.M., Dimic E.B., Rabrenovic, B.B. 2018. Phytochemical profile and antioxidant capacity of virgin

olive oil obtained from the olive cultivar 'Roghiani' from different regions of northern Libya. *Grasas y Aceites* 69: 2-10.

Essiari, M., Bachir, S., Zouhair, R., Chimi, H., Misbahi, H., Boudkhili, M. 2014. Influence de la Variété et du Milieu de Culture Sur la Composition en Acide Gras, en Stérols et en Polyphénols Totaux Pour les Huiles Vierges de Quatre Variétés D'olives de la Région de Saïs (Maroc). *European Journal of Scientific Research* 125: 95-114.

García-Villalba, R., Carrasco-Pancorbo, A., Oliveras-Ferraros, C., Vazquez-Martin, A., Menendez, J.A., Segura-Carretero, A., Fernandez-Gutierrez, A. 2010. Characterization and quantification of phenolic compounds of extra-virgin olive oils with anticancer properties by a rapid and resolutive LC-ESI-TOF MS method. *Journal of Pharmaceutical and Biomedical Analysis* 51: 416-429.

Gilbert-López, B., Valencia-Reyes, Z.L., Yufra-Picardo, V.M., García-Reyes, J.F., Ramos-Martos, N., Molina-Díaz, A. 2014. Determination of polyphenols in commercial extra virgin olive oils from different origin Mediterranean. *Food Analytical Methods* 7: 1824–1833.

Gómez-Rico, A., Salvador, M.D., La Greca, M., Fregapane, G. 2006. Phenolic and volatile compounds of extra virgin olive oil (Olea europaea L. Cv. Cornicabra) with regard to fruit ripening and irrigation management. *Journal of Agricultural and Food Chemistry* 54: 7130-7136.

Ilyasoglu, H., Beraat, O., Vera Van, H., Roland, V. 2010. Characterization of Aegean Olive Oils by Their Minor Compounds, *J Am Oil Chem Soc* 87: 627-36.

IOC, 2017. Determination of biophenols in olive oils by HPLC. International Olive Council. COI/T.20/Doc. No 29/ Rev.1 201, Madrid, Spain. 1-8 p.

IOC. 1996. Analyse spectrophotometrique dans l'ultraviolet. Conseil oléicole international. COI/ T20/ Doc 19 6 juin 1996, Madrid, Espagne. 17 p.

IOC. 2003. Classification des huiles d'olive. Normes internationales applicables à l'huile d'olive et à l'huile de grignon d'olive. Conseil Oléicole International. 9 p.

Issaoui, M., Flamini, G., Brahmi, F., Dabbou, S, Ben Hassine, K., Taamali, A., Chehab, H., Ellouz, M, Zarrouk, M., Hammamia, M. 2010. Effect of the growing area conditions on differentiation between Chemlali and Chétoui olive oils. *Food Chemistry* 119: 220-225.

Laincer, F., Iaccarino, N., Amato, J., Pagano, B., Pagano, A., Tenore, T., Tamendjari, A., Rovellini, P., Venturini, S., Bellan, G., Ritieni, A., Mannina, L., Novellino, E., Randazzo, A. 2016. Characterization of monovarietal extra virgin olive oils fromthe province of Béjaïa (Algeria). *Food Research International* 89: 1123-1133.

Laincer, F., Laribi, R., Tamendjari, A., Arrar, L., Rovellini, P., Venturini, S. 2014. Olive oils from Algeria : Phenolic compounds, antioxidant and antibacterial activities. *Grasas y Aceites* 65: 4-6.

Laribi, R., Laincer, F., Tamendjari, A., Rovellini, P., Venturini, S., Keciri, S., Arrar, L. 2011. Caractérisation de dix variétés d'huiles d'olive algérienne : étude du profil en composés phénoliques par HPLC. *La Rivista Italiana Delle Sostanze Grasse* 88: 161-171.

Lauri, I., Pagano, B., Malmendal, A., Sacchi, R., Novellino, E., Randazzo, A. 2013. Application of "magnetic tongue" to the sensory evaluation of extra virgin olive oil. *Food Chemistry* 140: 692-6929.

Manai-Djebali, H., Krichene, D., Ouni, Y., Gallardo, L., Sanchez, J., Osorio, E., Zarrouk, M. 2012. Chemical profiles of five minor olive oil varieties grown in central Tunisia. *Journal of Food Composition and Analysis* 27:109-119.

Mansouri, F., Benmoumen, A., Richard, G., Fauconnier, M.L., Sindic, M., Serghini-Caid, H., Elamrani, A. 2016. Characterization of monovarietal virgin olive oils from introduced cultivars in eastern Morocco. *Riv Ita Sost Gra* 93: 21-30.

ONFAA, 2016. *Observatoire national des filières agricole et agroalimentaire*. Note de conjoncture n°4 : Le suivi de compagne de l'huile d'olive. p. 7.

Pouyet, B., Ollivier, V. 2014. Réglementations sur l'étiquetage et la présentation des huiles d'olive. *OLC* 2: 1-7.

Ragusa, A., Centonze, C., Grasso, M.E., Latronico, M.F., Mastrangelo, P.F., Fanizzi, F.P., Maffia, M. 2017. Composition and Statistical Analysis of Biophenols in Apulian Italian EVOOs. *Foods* 6: 1-15.

Romero, N., Saavedra, J., Tapia, F., Sepúlveda, B., Aparicio, R. 2015. Influence of agroclimatic parameters on phenolic and volatile compounds of Chilean virgin olive oils and characterization based on geographical origin, cultivar and ripening stage. *Journal of the Science of Food and Agriculture* 96: 583-592.

Rovellini, P. 2008. Elenolic acid in virgin olive oil: liquid chromatography-mass spectrometry method. *La Rivista Italiana delle Sostanze Grasse* 85: 21-31.

Rovellini, P., Cortesi, N., Fedeli, E. 1997. Analysis of flavonoids from *Olea europaea* by HPLC-UV and HPLC-ES-MS. *La Rivista Italiana delle Sostanze Grasse* 74: 273-279.

Semenuik, N. 2013. *Mes Petites Mixtures d'Huiles d'Olive*. Rustica éditions, Paris, France.

Sönmez, A., Özdikicierler, O., Saygin Gümüşkesen, A. 2018. Evaluation of olive oil quality during the ripening of the organic cultivated olives and multivariate discrimination of the variety with a chemometric approach. *La Rivista Italiana delle Sostanze Grasse* 95: 173-181.

Tamendjari, A., Sait, S., Laincer, F., Rovellini, P., Venturini, S. 2018 Quality, antioxidant and antibacterial activity of olive oil from wild olives (Oleasters). *La Rivista Italiana delle Sostanze Grasse* 95: 195-203.

Tamendjari, A., Angerosa, F., Bellal, M.M. 2004. Influence of *Bactrocera oleae* infestation on olive oil quality during ripening of *Chemlal* olives. *Italian Journal of Food Science*

16(3): 343-354.

Tanouti, K., Serghini-Caid, H., Chaieb, E., Benali, A., Harkous, M., Elamrani, A. 2011. Quality improvement of olive oils produced in the eastern Morocco. *Les technologies de Laboratoire* 6: 1-12.

Taticchi, A., Esposto, S., Veneziani, G., Urbani, S., Selvaggini, R., Servili, M. 2013. The influence of malaxation temperature on activity of polyphenoloxidase and peroxidase on phenolic composition of virgin olive oil. *Food Chemistry* 136: 975-983.

Union international de la chimie pure et appliqué (U.I.C.P.A). 1979. *Méthode d'analyses des matières grasses et dérivés*. Edition ETIG, Paris.

Vekiari, S.A., Koutsaftakis, A. 2002. The effect of different processing stages of olive fruit on the extracted olive oil polyphenol content. *Grasas y Aceites* 53(3): 304-308.

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