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Oil fatty acid composition of eighteen Mediterranean olive varieties cultivated under the arid conditions of Boughrara (southern Tunisia)

By **Wissem Zarrouk,**[a] **Bechir Baccouri,**[a] **Wael Taamalli,**[a] **Ahmed Trigui,**[b] **Douja Daoud**[a] and **Mokhtar Zarrouk**[a*]

[a] Laboratoire Caractérisation et Qualité de l'Huile d'Olive, Centre de Biotechnologie de Borj Cedria, BP 901, 2050 Hammam-Lif, Tunisia.
[b] Institut de l'Olivier, BP 263, 3018 Sfax, Tunisia.
(*Corresponding author: e-mail: mokhtar.zarrouk@cbbc.rnrt.tn)

RESUMEN

Composición de ácidos grasos de dieciocho variedades de aceituna mediterráneas cultivadas en las condiciones áridas de Boughrara (zona meridional de Túnez).

En este estudio, dieciocho variedades de aceituna procedentes de España, de Francia, de Italia, de Grecia y de Argelia, cultivadas en la estación experimental del olivo de Boughrara (región árida de Túnez), fueron evaluadas para el rendimiento en aceite y la composición de ácidos grasos. El análisis de la varianza mostró diferencias significativas entre todas las variedades ($p < 0.01$). El análisis de "clusters" jerárquico clasificó las variedades en tres grandes grupos. El primer grupo incluía un subgrupo compuesto por siete variedades de aceituna Changlot Real, Koroneiki, Verdial de Vélez-Málaga, Coratina, Lechín de Granada, Cornezuelo y Leccino, que se caracterizan por su alto rendimiento en aceite, alto contenido en oleico y bajo contenido en ácidos palmítico y linoleico. Las composiciones de ácidos grasos de aceites provenientes de estas variedades se conforman con estándares internacionales y son mejores si las comparamos con la de Chemlali (el cultivo más abundante en Túnez). Finalmente, los ácidos grasos mayoritarios (palmítico (C16:0), oleico (C18:1) y linoleico (C18:2)) de nueve de los aceites de oliva virgen estudiados fueron comparados con los de las mismas variedades cultivadas en sus áreas originarias. A excepción de los aceites Koroneiki y Olivière que mostraron una composición de ácidos grasos inalterable y del aceite Cornezuelo en el que se observó un aumento del nivel de ácido oleico y un descenso del nivel de ácido linoleico, la mayoría de los aceites mostró disminución de ácido oleico y aumento de los porcentajes de ácido palmítico y linoleico, comparándolos con los obtenidos de las aceitunas cultivadas en su lugares de origen.

PALABRAS CLAVE: Aceite de oliva – Composición de ácidos grasos – Variedades mediterráneas.

SUMMARY

Oil fatty acid composition of eighteen Mediterranean olive varieties cultivated under the arid conditions of Boughrara (southern Tunisia).

In this study, eighteen olive varieties, originating from Spain, France, Italy, Greece and Algeria, and maintained at the olive experimental station of Boughrara (arid region of Tunisia) were evaluated for their oil yield and fatty acid composition. The analysis of variance revealed significant differences among varieties for all traits ($p < 0.01$). The Hierarchical Cluster Analysis (HCA) classified the varieties into three main groups. The first group included a subgroup which is composed of seven olive varieties (Cornezuelo, Verdial de Vélez-Málaga, Leccino, Coratina, Koroneiki, Lechín de Granada and Changlot Real) characterized by high oil yield with high oleic, low palmitic and linoleic acid contents. The fatty acid compositions of the oils from these varieties comply with international standards and show more beneficial characteristics than the oil obtained from Chemlali: the most abundant olive cultivar in Tunisia. Finally, the main fatty acids (palmitic (C16:0), oleic (C18:1) and linoleic (C18:2)) of nine of the studied virgin olive oils were compared to those sampled from their traditional areas. Except for Koroneiki and Olivière oils which showed an unchanged fatty acid composition and for Cornezuelo oil in which the level of oleic acid raised and the level of linoleic acid decreased, most of oils showed a decrease in oleic acid rates and an increase in palmitic and linoleic acid percentages as compared to those from their original sites.

KEY-WORDS: Fatty acid composition – Mediterranean varieties – Olive oil.

1. INTRODUCTION

Virgin olive oil represents one of the major high-quality agricultural products in Tunisia. Besides the generally acknowledged good flavor and organoleptic excellence of virgin olive oil, it also has highly appreciated nutritional characteristics thanks to its balanced fatty acid composition (Ryan *et al.,* 1998; Sánchez Casas *et al.,* 1999; Salvador *et al.,* 2001). A healthy diet must contain a limited amount of saturated fatty acids to reduce the total cholesterol content and a high amount of monounsaturated fatty acids which prevent the risk of cardiovascular diseases, reduce the insulin body-requirement and decrease the plasma concentration of glucose (D'Imperio et al., 2007). Moreover, the relationship between the intake of olive oil, the richest dietary source of monounsaturated fatty acid and breast cancer risk and progression is a current issue of discussion (Servili *et al.,* 2004). It is well established by many authors that the fatty acid composition of olive oil is strongly influenced by cultivar (Tsimidou *et al.,* 1993; Zarrouk et al., 2008), the maturation stage of fruit (Synouri *et al.,* 1995) and the zone of origin characterized by certain pedoclimatic factors as well as other minor area parameters (Ranalli *et al.,* 1997). Nevertheless, a varietal parameter seems to be the most important and determining factor. The punctual description of a specific cultivar on the basis of its fatty acid content is important since fatty acid content is one of the quality parameters of olive oil.

In Tunisia, there are two main olive cultivars: Chemlali and Chétoui. The Chemlali cultivar contributes to 80% of the national oil production. It is a productive variety, well adapted to our severe environmental conditions and leads to the production of an olive oil fatty acid composition characterized by high levels of palmitic and linoleic acids and sometimes low levels of oleic acid. A major effort has been made recently to improve the quality of the olive oil produced in Tunisia. Thus, the aim of increasing the quality standards for virgin olive oil is continuously stimulating the search for cultivars which have better oil quality. The use of different cultivars from other countries could be interesting based on their agronomical as well as their oil composition. However, before using new cultivars, their behavior under Tunisian pedo-climatic conditions must be evaluated. In order to find out which variety is the best for growing in extreme climatic conditions, the lipid substrate composition of olive oils obtained from some Mediterranean varieties grown in the olive experimental field of Boughrara (Sfax) in Tunisia have been checked. Furthermore, we examined the influence of variety and environmental conditions on the fatty acid composition of virgin olive oils from the involved varieties.

2. MATERIALS AND METHODS

2.1. Plant material and growing area

The study is carried out on eighteen foreign varieties of olive-trees (Table 1) grown at the Experimental Station of Boughrara, Sfax (35° 00'N; 10° 33'E; 128 m asl; approx. 220 mm rain year^{-1}; mean day/night temperature 15°-29°C) with an arid climate and slightly alkaline soil [pH approx. 7.5] (Gargouri and Mhiri, 2002). The sandy soils of Boughrara are highly permeable (15-20 cm h^{-1}) and have a low water-retention capacity [5-6% (w/w) of dry soil] (Gargouri and Mhiri, 2002), making them suitable for olive trees grown in arid zones (Loussert and Brousse, 1978). The olive trees were never submitted to agronomical treatment.

2.2. Olive processing

Three representative samples from each variety were handpicked at the same stage of maturity, when the fruit skin was light-violet in color. Ripeness index (RI) was determined according to the method developed by the Agronomic Station of Jaèn, Spain, which defines RI as a function of skin and pulp color (Uceda and Hermoso, 1998). Olives were processed in a laboratory olive-mill (MC2; Ingenieriay Sistemas, Seville, Spain) consisting of a hummer crusher, a mixer, and a basket centrifuge. The olive past was mixed for 30 min at room temperature, centrifuged (without the addition of water), then transferred io dark glass bottles and kept at 4°C prior to analysis. Three replicates were carried out in each analytical determination.

Table 1
Variety name, original country, use and average fruit fresh weight of analyzed olives

Olive varieties	Original site	Use	Fruit fresh weight (g)*
Changlot Real	Spain	Oil	2.37 ± 0.05
Olivière	France	Oil	3.90 ± 0.07
Koroneiki	Greece	Oil	1.02 ± 0.02
Verdial de Vélez-Málaga	Spain	Oil	3.86 ± 0.05
Cayon	France	Oil	1.90 ± 0.22
Coratina	Italy	Oil	2.45 ± 0.07
Lechín de Granada	Spain	Oil	1.77 ± 0.08
Cornezuelo	Spain	Oil & Table	2.42 ± 0.04
Sigoise	Algeria	Oil & Table	3.96 ± 0.06
Leccino	Italy	Oil	2.44 ± 0.06
Madural	Portugal	Oil & Table	3.31 ± 0.07
Arbequina	Spain	Oil	1.67 ± 0.09
Agouromanakolia	Greece	Oil	2.80 ± 0.20
Lucques	France	Table	4.20 ± 0.19
Grossane	France	Oil & Table	3.69 ± 0.07
Picholine	France	Oil & Table	3.64 ± 0.18
Lechín de Sevilla	Spain	Oil	3.47 ± 0.16
Verdale de l'Hérault	France	Oil & Table	5.32 ± 0.20
Chemlali	Tunisia	Oil	0.98 ± 0.15

*Average of three determinations.

2.3. Oil content

For the determination of oil content, 40g of olive samples were dried in an oven at 80°C to constant weight. The dry olives were extracted with petroleum ether using a Soxhlet apparatus. The results were expressed as percentage of dry matter (DM).

2.4. Oil analysis

The fatty acid composition of the oils was determined by gas chromatography (GC) as fatty acid methyl esters (FAMEs). FAMEs were prepared by saponification/methylation with sodium methylate according to European Regulations (EEC 2568/91). A chromatographic analysis was performed in a Hewlett-Packard model 4890D gas chromatograph equipped with a 30m x 0.25 mm x 0.25µm film thickness fused Silica capillary column (Innowax) coupled to a flame ionization detector (column temperature 210°C). Both the injector and the detector were maintained at 230 and 250°C, respectively. Nitrogen was used as the carrier gas at 1ml/min with Split injector system (Split ratio 1:100). Fatty acids were identified by comparing their retention times with those of standard compounds.

2.5. Statistical analysis

Results are shown as the mean values and standard deviations of independent measurements. A cluster analysis was conducted on the Euclidean distance matrix based on the normalized data of virgin olive oil samples using the Ward method. The statistical analysis was performed using the XLSTAT software, Version 2008.1.02 (Addinsoft) and the SPSS 13.0 for windows (SPSS Inc., 2004).

3. RESULTS AND DISCUSSION

The fatty acid composition has previously been used by a number of authors as a parameter for oil classification (Bouskou, 1996; Ranalli et al., 1997; Motilva et al., 2001). Fatty acid evaluation was performed on the olive oils following the usual product analyses. GC applied to the olive oil samples allowed for the identification of the following fatty acids: palmitic (C16:0), palmitoleic (C16:1), stearic (C18:0), oleic (C18:1), linoleic (C18:2), linolenic (C18:3) and arachidic (C20:0) acids. Their relative percentages and the corresponding ratios in addition to the agronomic parameters such as average fruit fresh weight and oil yield on dry weight basis were evaluated in this study. The analysis of variance, estimated by the coefficient of variation, revealed significant differences among cultivars for all traits ($P<0.01$) (Table 2). Oleic acid/linoleic acid (C18:1/C18:2) and Monounsaturated fatty acids/polyunsaturated fatty acids (MUFAs/PUFAs) ratios, C18:2 and C16:1 percentages and the average fruit fresh weight showed wide variation, while fruit oil content on dry weight basis, C18:1, C16:0 and unsaturated fatty acid (UFAs) percentages showed a narrower range of variation.

The average fruit fresh weight is a crucial agronomic parameter for a preliminary selection of variety for table olives, oil destination or even both uses. A great variability in the means of the average fruit fresh weight was observed among the studied olive varieties (Table 1) it ranged from a minimum of 1.02 (Koroneiki) to 5.32g (Verdale de l'Hérault). Oil content does not constitute a criterion of oil quality determination but especially a criterion to be envisaged during the varietal selection. As oil content is influenced by olive flesh humidity at the time of olive harvest (Sánchez Casas et al., 1999), this parameter was expressed as percent of dry matter (Figure 1). The oil content for all the olives studied varied significantly among cultivars. So, Grossane fruit had the lowest oil content (38.6%), while Verdale de l'Hérault fruit recorded the highest content (59%), the other cultivars presented intermediate values. According to the classification of Tous and Romero (1993), Changlot Real, Koroneiki, Verdial de Vélez-Málaga, Coratina, Lechín de Granada, Cornezuelo,

Table 2
Descriptive statistical analysis of the variables from the studied olive varieties

	Minimum	Maximum	Mean*	SD	CV (%)
C16:0 (%)	11.210	20.740	14.698	2.569	17.480
C16:1(%)	0.670	2.910	1.663	0.680	40.889
C18:0 (%)	1.680	4.330	2.642	0.709	26.841
C18:1 (%)	47.190	78.010	66.141	7.973	12.055
C18:2 (%)	3.590	27.560	12.828	6.194	48.283
C18:3 (%)	0.690	1.480	1.023	0.232	22.682
C20:0 (%)	0.000	0.830	0.474	0.155	32.623
C18:1/ C18:2 ratio	1.712	21.730	7.194	4.921	68.402
UFAs (%)	75.520	86.280	81.655	2.514	3.079
MUFAs/ PUFAs	1.727	17.654	6.472	3.973	61.395
Average fruit fresh weight (g)	0.930	5.400	2.905	1.129	38.866
Oil content (fruit dry wt basis) (%)	37.200	63.480	48.146	6.229	12.937

*Mean of three replicates

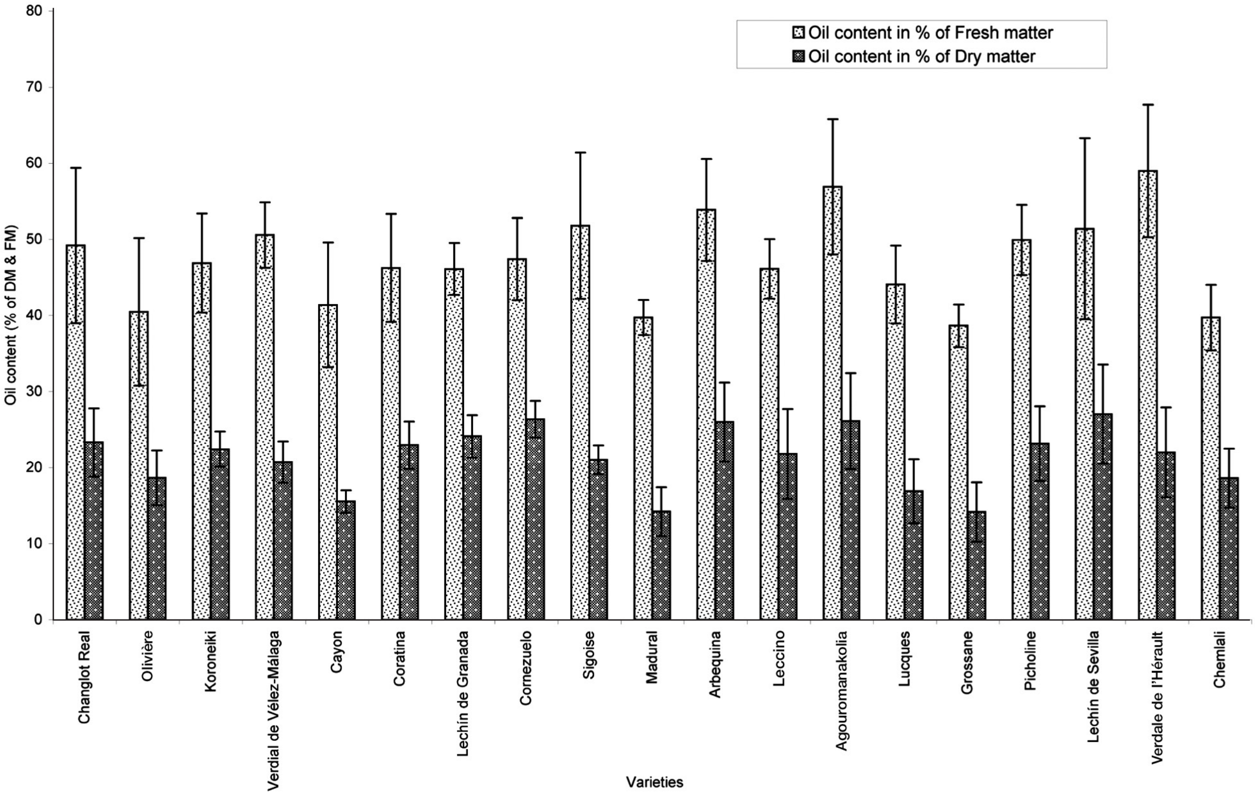

Figure 1
Oil yield of the studied olive varieties compared to that of Chemlali.

Sigoise, Arbequina, Leccino, Agouromanakolia, Picholine, Lechín de Sevilla and Verdale de l'Hérault could be considered as high oil yielding cultivars (oil content $>$ 46%) while Olivière, Cayon, Madural, Lucques and Grossane could be considered as medium oil yielding cultivars (oil content varied between 38.6 and 44%).

As can be seen in Table 3, the fatty acid composition of the studied oils is variable depending on the genotype variety. Monounsaturated fatty acids have great importance because of their nutritional implication and effect on the oxidative stability of oils. Oleic acid is the main monounsaturated fatty acid and is present in a wide range of concentrations (47.23–77.5%). C16:1 content varied between 0.70 and 2.89% according to varieties. The level of C16:0, the major saturated fatty acid in olive oil, ranged from 11.22 (Sigoise) to 19.24% for Grossane. The content of stearic acid, another important saturated acid, is within the range of 1.7- 4.3 % for Arbequina and Verdial de Vélez-Málaga oils (Table 3). For the arachidic acid, all the studied varieties showed values lower than the limit of 0.6% established for the extra virgin olive oil except for the Verdial de Vélez-Málaga variety. Polyunsaturated fatty acids are very important for human nutrition. With respect to the linoleic acid, which is negatively correlated to the stability of virgin olive oil as it is much more susceptible to oxidation than monounsaturated fatty acids, the highest percentage was observed in Verdale de l'Hérault oil (27.51%), whereas the lowest percentage was found in Olivière oil (3.6%). The other varieties show percentages ranging between 5.22 and 21.72% (Table 3). Linolenic acid, which presents the highest level of unsaturation of olive oil, was found to exceed the limit of 1% established for the extra virgin olive oil for Cayon, Sigoise, Grossane, Picholine, Lechín de Sevilla and Verdale de l'Hérault varieties. According to the literature, the International Olive Council norm (IOOC, 2008) for the total linolenic acid is not specific for many olive varieties. Thus, levels of C18:3 in excess of 1% have also been reported by El Antari et al. (2003) in Moroccan oils with up to 1.43% in fruit flesh. Ravetti (1999) reported levels of up to 1.42% C18:3 in Argentinean oils. Similar results were shown in New Zealand (Meehan, 2001) with up to 1.5% and in Lecce (Italy), C18:3 levels in a series of olive samples ranged from 1.1% to 1.4% (Dettori and Russo, 1993). Paz Romero *et al.,* 2003 attributed variation to seasonal differences, particularly water availability.

Fatty acid composition, and noticeably C18:1/C18:2 ratio, affects the taste of virgin olive oil, a condiment which is largely responsible for the taste and healthy effects of the Mediterranean diet (Bouskou, 1996). Moreover, it has been proven that the ratio between unsaturated fatty acids can contribute to cultivar characterization since it is known that the acidic profile of virgin olive oils is mainly affected by the fruit variety (Stefanoudaki *et al.,* 1999; Zarrouk *et al.,* 2008). The UFAs percentage is variable according to the cultivar; it oscillates between 77.72 (Grossane) and 86.01%

Table 3
Mean values of fatty acid composition (%) and calculated ratios in virgin olive oils from the involved varieties, as compared to that of the national cultivar 'Chemlali'*.

Varieties	Fatty acids							C18:1/ C18:2	UFAs	MUFAs/ PUFAs
	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	C20:0			
Changlot Real	11.80 ± 0.09*	1.00 ± 0.05	3.40 ± 0.07	72.00 ± 0.25	9.60 ± 0.16	0.91 ± 0.06	0.60 ± 0.03	7.50 ± 0.15	83.51 ± 0.07	6.95 ± 0.17
Olivière	13.30 ± 0.11	1.59 ± 0.07	2.01 ± 0.05	77.50 ± 0.89	3.60 ± 0.03	0.91 ± 0.06	0.50 ± 0.03	21.53 ± 0.36	83.60 ± 0.90	17.52 ± 0.26
Koroneiki	12.93 ± 0.30	1.21 ± 0.05	2.48 ± 0.01	74.40 ± 0.08	7.10 ± 0.06	0.86 ± 0.01	0.48 ± 0.06	10.48 ± 0.10	83.57 ± 0.09	9.50 ± 0.10
Verdial de Vélez-Málaga	12.68 ± 0.03	0.70 ± 0.05	4.30 ± 0.06	73.28 ± 0.90	6.22 ± 0.15	0.91 ± 0.04	0.79 ± 0.07	11.79 ± 0.43	81.11 ± 0.74	10.38 ± 0.40
Cayon	12.14 ± 0.06	2.26 ± 0.01	2.72 ± 0.05	75.59 ± 1.33	5.84 ± 0.26	1.39 ± 0.16	_	12.49 ± 0.80	85.08 ± 1.19	10.77 ± 0.40
Coratina	13.47 ± 0.16	1.08 ± 0.02	2.68 ± 0.01	70.88 ± 1.87	9.76 ± 0.18	0.98 ± 0.01	0.48 ± 0.02	7.26 ± 0.29	82.70 ± 1.75	6.70 ± 0.25
Lechín de Granada	12.71 ± 0.46	0.89 ± 0.03	3.72 ± 0.03	72.73 ± 1.02	8.27 ± 0.50	0.79 ± 0.07	0.48 ± 0.02	8.81 ± 0.65	82.69 ± 0.49	8.13 ± 0.62
Cornezuelo	13.97 ± 0.29	1.87 ± 0.03	3.89 ± 0.04	73.11 ± 0.91	5.22 ± 0.01	0.90 ± 0.02	0.58 ± 0.02	14.01 ± 0.15	81.09 ± 0.87	12.27 ± 0.17
Sigoise	11.22 ± 0.02	1.03 ± 0.27	2.03 ± 0.03	70.89 ± 0.71	12.87 ± 0.03	1.22 ± 0.16	0.31 ± 0.01	5.51 ± 0.05	86.01 ± 0.53	5.11 ± 0.10
Leccino	15.40 ± 0.36	1.71 ± 0.03	2.37 ± 0.09	67.90 ± 1.04	10.80 ± 0.06	1.00 ± 0.07	0.37 ± 0.00	6.29 ± 0.13	81.42 ± 0.92	5.89 ± 0.15
Madural	17.86 ± 0.28	2.07 ± 0.01	2.28 ± 0.03	63.10 ± 0.77	12.70 ± 0.16	1.00 ± 0.06	0.46 ± 0.01	4.97 ± 0.12	78.88 ± 0.69	4.76 ± 0.09
Arbequina	17.42 ± 0.39	2.89 ± 0.04	1.70 ± 0.04	60.07 ± 0.93	16.24 ± 0.22	0.70 ± 0.03	0.59 ± 0.04	3.70 ± 0.01	79.89 ± 1.14	3.72 ± 0.01
Agouromanakolia	13.43 ± 0.16	1.09 ± 0.01	2.90 ± 0.04	61.62 ± 0.67	19.18 ± 0.51	0.71 ± 0.04	0.50 ± 0.03	3.21 ± 0.12	82.60 ± 0.21	3.15 ± 0.11
Lucques	16.32 ± 0.08	2.19 ± 0.02	2.31 ± 0.01	59.76 ± 0.26	17.27 ± 0.07	0.99 ± 0.02	0.50 ± 0.02	3.46 ± 0.03	80.20 ± 0.25	3.39 ± 0.03
Grossane	19.24 ± 0.32	2.69 ± 0.02	2.30 ± 0.02	58.93 ± 0.72	14.69 ± 0.29	1.41 ± 0.16	0.61 ± 0.04	4.01 ± 0.13	77.72 ± 0.57	3.83 ± 0.09
Picholine	14.14 ± 0.30	1.00 ± 0.03	2.50 ± 0.05	63.04 ± 0.66	17.07 ± 0.12	1.43 ± 0.04	0.52 ± 0.01	3.69 ± 0.06	82.54 ± 0.47	3.46 ± 0.06
Lechín de Sevilla	13.30 ± 0.09	1.32 ± 0.03	1.81 ± 0.07	59.72 ± 0.62	21.72 ± 0.72	1.09 ± 0.01	0.34 ± 0.17	2.75 ± 0.12	83.85 ± 0.20	2.68 ± 0.11
Verdale de l'Hérault	18.29 ± 0.06	2.79 ± 0.02	1.98 ± 0.03	47.23 ± 0.08	27.51 ± 0.18	1.40 ± 0.06	0.40 ± 0.03	1.72 ± 0.01	78.92 ± 0.08	1.73 ± 0.01
Chemlali	19.65 ± 1.94	2.20 ± 0.24	2.82 ± 0.87	54.93 ± 0.56	18.07 ± 0.90	0.85 ± 0.09	0.52 ± 0.05	2.99 ± 0.21	76.04 ± 1.62	2.97 ± 0.24
Norm (IOC, 2008)	7.5-20	0.3-3.5	0.5-5	55-83	3.5-21	≤1	≤0.6	–	–	–

* Data are expressed as mean values ± SD; UFAs, unsaturated fatty acids; MUFAs, mono-unsaturated fatty acids; PUFAs, poly -unsaturated fatty acids

(Sigoise). The Olivière variety is distinguishable from the others due to its considerably higher C18:1/C18:2 and MUFAs/PUFAs ratios (21.53 and 17.52, respectively).

The cluster analysis is conducted on the Euclidean distance matrix based on the virgin olive oil data using the Ward method. The resulting dendrogram (Figure 2) revealed three major groups. The first group includes nine varieties: Changlot Real, Olivière, Koroneiki, Verdial de Vélez-Málaga, Cayon, Coratina, Lechín de Granada, Cornezuelo and Leccino showing high ratios of C18:1/C18:2 (6.29-21.53) and MUFAs/PUFAs (5.89-17.52). In addition, this group showed two subgroups, one of them is composed of Cayon and Olivière varieties which have medium oil content while the remainder of the varieties belonging to subgroup 1 have olives with high oil content. The second and the third groups consisted of four (Agouromanakolia, Sigoise, Picholine and Lechín de Sevilla) and five (Madural, Lucques, Grossane, Arbequina, and Verdale de l'Hérault) varieties, respectively. In contrast to the first group, cultivars in groups 2 and 3 have oils with low oleic (47.23-70.89%) and high linoleic (12.70-27.51%) acid percentages and low ratios of C18:1/C18:2 (1.72-5.51) and MUFAs/PUFAs (1.73-5.11). The cultivars in group 3, to which the Chemlali cultivar belongs, have oils richer in palmitic (16.32-19.24 % against 11.22-14.14 %) and palmitoleic acids (2.07-2.89% against 1.00-1.32%) and poorer in UFAs (77.72-80.20 against 82.54-86.01%) when compared to cultivars from group 2.

As previously reported, C18:1, C18:2 and their corresponding ratio in addition to the MUFAs/PUFAs ratio, are relevant in describing the olive oil samples. Similar results have been reported for the evaluation of fatty acid compositions of the olive oils from cultivar collections. Tous et al. (2005) and Uceda et al. (2005) identified different groups from the evaluations of 28 and 78 mono-varietal olive oils, respectively, by their fatty acid composition. In both cases, the main criteria for classification into groups was similar to the one described here. However, this preliminary evaluation can surely be improved by considering other minor chemical components of virgin olive oil such as individual phenolic compounds (Gómez-Alonso et al., 2002), volatiles (Mahjoub Haddada et al., 2007) and sterols and alcohols (Rivera de Álamo et al., 2003) which, as families of substances, have proven to be very important in the chemical classification of virgin olive oil varieties.

As similar methods were used by the scientific community for the analysis of olive oil fatty acid compositions determined by gas chromatography, and with regard to the not significant differences observed in the maturity index between the studied olive varieties reported in the literature (ranging between 3 and 4.5) and that of varieties under this study, we considered it useful to compare between our data and the data reported in the bibliography. Then, in order to investigate the effect of the environmental conditions on olive oil fatty acid composition, we compared the rates of palmitic, oleic and linoleic acids of nine olive varieties from the area of Boughrara to those of their original sites according to the literature (Table. 4). According to these results, the olive varieties such as Sigoise, Picholine, Arbequina and Coratina cultivated in their traditional growing areas showed a high oleic and low linoleic and palmitic acid contents; cultivated in Sfax, one records a relatively lower rate of oleic acid and higher rates of palmitic and linoleic acids. The impact of the environmental conditions was greater on such varieties which showed clear differences between the geographical area of production for oils from their original sites and Tunisia. The levels of the main fatty acids of Leccino oil from Sfax also show the same variations by comparison to the stable composition of this variety registered in Italy. Therefore, this Italian variety cannot preserve its specific fatty acid composition when it was cultivated under the environmental conditions of Boughrara. However, under the pedoclimatic conditions from Andalucia (Spain), Paz Aguilara et al. (2005) reported in their research that Leccino could maintain its characteristic fatty acid composition.

For the Madural variety, the same changes were observed in the palmitic and oleic acid levels while a slight decrease in the linoleic acid percentage was registered. However, a better fatty acid composition was observed in Cornezuelo oil in comparison to its traditional composition described in Spain with respect to the levels of oleic and linoleic acids.

Concerning Koroneiki and Olivière oils, no significant differences were observed in their fatty acid composition by comparison to those found in their original site. Thus, such varieties showed good pedoclimatic adaptability for preserving their potential and their characteristic chemical oil compositions apart from their original site.

4. CONCLUSIONS

This study allowed us to depict seven olive varieties (Cornezuelo, Verdial de Vélez-Málaga, Leccino, Coratina, Koroneiki, Lechín de Granada and Changlot Real) that showed higher oil yield and better fatty acid composition when compared to 'Chemlali'; the most abundant olive cultivar in Tunisia. In a future work, these varieties will be further explored for oil stability against oxidation, and related anti-oxidant levels, sterolic composition, triterpenic alcohols, etc. before recommendation for a large-scale cultivation.

5. ACKNOWLEDGMENTS

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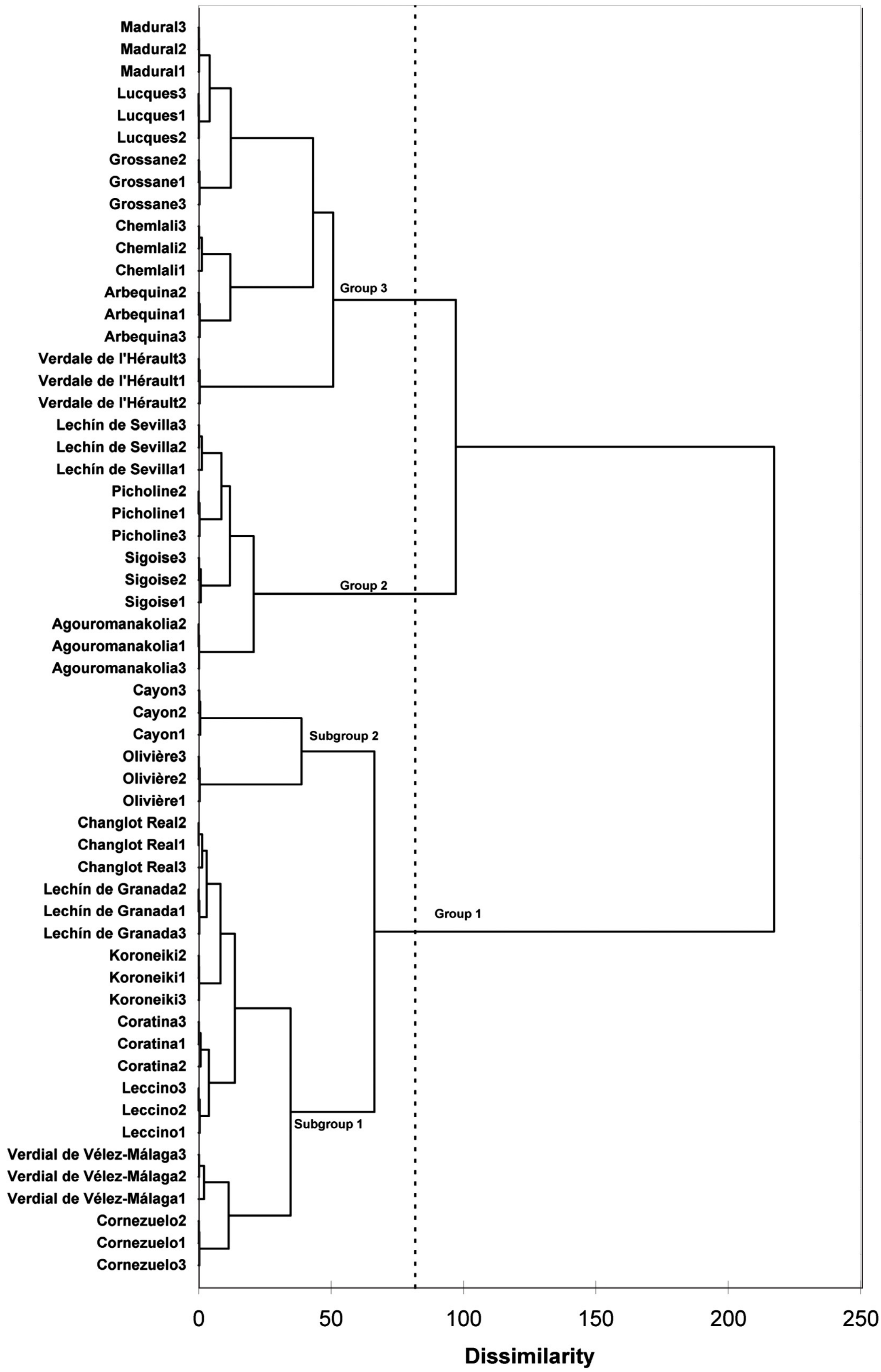

Figure 2
Dendrogram of the normalized data of virgin olive oil samples using Euclidean distances and the Ward algorithm.

Tabla 4
Change in the main fatty acids of olive oil (as percentage of total fatty acids) of nine olive varieties according to the origin of plantation.

Olive varieties	Main fatty acids	Boughrara (Sfax)	Original site*
Sigoise	C16:0	11.2	6.0
	C18:1	70.9	82.0
	C18:2	12.9	7.4
Picholine	C16:0	14.1	11.0
	C18:1	63.0	73.7
	C18:2	17.1	10.2
Koroneiki	C16:0	13.0	10.4
	C18:1	74.4	76.2
	C18:2	7.1	8.3
Arbequina	C16:0	17.4	14.9
	C18:1	60.1	70.6
	C18:2	16.2	9.1
Olivière	C16:0	13.3	12.6
	C18:1	77.5	78.8
	C18:2	3.6	3.9
Cornezuelo	C16:0	14.0	13.3
	C18:1	73.1	67.8
	C18:2	5.2	12.9
Madural	C16:0	17.9	10.3
	C18:1	63.1	72.6
	C18:2	10.8	11.4
Leccino	C16:0	15.4	14.6
	C18:1	67.9	76.1
	C18:2	10.8	5.9
Coratina	C16:0	13.47	11.5
	C18:1	70.88	78.1
	C18:2	9.76	6.3

*Sánchez Casas et al., 2003 ; Koutsaftakis et al., 2000 ; Matos Luís et al., 2007 ; Ollivier et al., 2000 ; Pardo et al., 2007 ; Poiana and Mincione, 2004 ; Servili et al., 2007 ; Talantikite and Ait Amar, 1988).

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