Biochemical and Pomological Variability of Several Autochthonous Olive Cultivars Grown in Algeria

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This work aimed to characterise the morphological traits of olives and physico-chemical of oil issued from 10 endemic cultivars harvested in the north-east of Algeria. The pomological parameters of the fruits showed a very significant difference ($p < 0.0001$) between the studied cultivars. Quality indices indicated that olive oil varieties belong to the extra virgin and virgin categories. Highly significant differences ($p < 0.0001$) were noted between the 10 varieties studied for the analytical parameters examined (fatty acid composition, total phenol, chlorophyll, and carotenoid content). *Boughenfous* showed the highest values in oleic acid with (75.15%) and in total phenols with 435.88 (mg of Gallic acid/kg of olive oil). Phenolic compounds (hydroxytyrosol, tyrosol, oleocanthal, total phenolic compounds) have shown important differences between varieties. The principal component analysis carried out on the profile of total fatty acids distinguishes 5 groups, group 2 and 3 proved to be the most interesting in terms of nutritional characteristics, they include three cultivars, characterised by the highest levels of oleic acid and MUFA and the MUFA/PUFA ratio. These results confirm the importance of the varietal character in determining the chemical characteristics of the oil. To enhance the olive sector, this characterisation must be extended to other secondary olive cultivars that are unexplored.
Keywords: Algerian cultivars, characterisation, fatty acid profile, chemical composition, HPLC-UV, fruit characteristics.

1. INTRODUCTION

Olive cultivation (*Olea europaea* L.) is one of the oldest crops in the world [1]**.** Olive tree is grown mainly in the Mediterranean region (Spain, Italy, Greece, Tunisia, Turkey, Morocco, and Algeria) for climatic reasons [2], and for the high nutritional value of its products (oil and table olives) and its economic importance [3]. Most of the olive production is intended for oil extraction and the other part to produce table olives [1]. It has many varieties with a significant phenotypic diversity [5]. The work of Hauville [6] in Algeria distinguished more than 150 varieties of olive trees. Although the Algerian olive growing heritage is rich in varieties, our traditional olive growing is dominated by two main varieties, *Chemlal* and Sigoise. *Chemlal* olives are used only for oil extraction; this cultivar is grown mainly in Kabylie (central Algeria) and represents 40% of the national olive area. The *Sigoise* variety that represents 20% is cultivated in the west of the country for its dual use (the quality of its oil and table olives). The other Algerian cultivars have a limited implantation and distribution. The olive sector has experienced significant growth in recent years, from 200,000 ha in 2011 to 401,181 ha in 2015 [7]. Several studies have focused on the nutritional and organoleptic properties of olive oil [8], which is a key factor in the healthy aspects attributed to the Mediterranean diet [9]. The benefits of virgin olive oil are mainly attributed both to its high oleic acid content which contributes to the balance of the amount of polyunsaturated fatty acids and

its richness in phenolic compounds, which act as natural antioxidants and can contribute to the prevention of several human diseases [10]. These beneficial traits, usually associated with the genotype of the cultivar, highlight the need to identify characteristics of olive oil that will ensure its authenticity [11]. The chemical composition of extra virgin olive oil is influenced by the olive cultivar, pedoclimatic conditions, geographical site, and stage of maturity [12]. In terms of genetic diversity, monovarietal olive oils, produced from a specific cultivar, have particular physical and biochemical characteristics and attributes that result in distinctive composition and performance [11]. Additionally, many pre-harvest and post-harvest factors are involved in the quality of olive fruit and its oil compositions [13].
In this context, the purpose of this study concerns the physicochemical and pomological characterisation of 10 Algerian endemic cultivars of olive tree (*Olea* L.) maintained at the national collection of the Takerietz demonstration farm (municipality of Souk Oufella, wilaya of Bejaïa).

2. MATERIAL AND METHODS

2.1. SAMPLING

This study includes 10 cultivated olive varieties of local population (Table I). The olives of the different cultivars were harvested during 2018-2019 at the experimental station of the Technical Institute of Fruit Trees and Vines, Sidi-Aich, Bejaia (Algeria). The geographical coordinates of the station area are as follows: latitude: 36°58'19" North, longitude: 4°66'69" East. Approximately 3 to 5 kg of olives were harvested manually from three trees for each variety. The sampling was done at man's height around the tree canopy. The extraction of olive oil was carried out using an oleodosor, a discontinuous two-phase cold centrifugation system. The extracted oil was decanted and stored in labelled opaque glass bottles, at a cold temperature (4°C) until analysis.

Table I - Characteristics of the plant material

Cultivars	Use
Bouchouk Lafayette	Dual purpose
Souidi	Oil
Aghchren d'El Ousseur	Dual purpose
Azeradj	Dual purpose
Boughenfous	Oil
Aguenaou	Dual purpose
Aghchren de Titest	Dual purpose
Aberkane	Dual purpose
Limli	Oil
Sigoise	Dual purpose

2.2. MORPHOLOGICAL CHARACTERS

The characters were evaluated according to the method of the International Olive Council [14]. The maturity index method consists of evaluating the colour of the skin and the pulp of the fruit. 100 olives were chosen randomly, ordered into seven groups from 0 to 7. The average fruit and stone weight (g) were determined on 40 fruits for each variety. The other characteristics such as flesh weight and flesh percentage were estimated by subtraction and ratios between the measured characteristics. To determine the percentage of humidity, about 50 g of olive samples were weighed and dried at 105°C in an oven, until a constant mass was reached. The oil content of the olives was determined by the Soxhlet method using a quantity of 20 to 30 g of crushed and dried olive paste for each cultivar.

2.3. QUALITY INDICES

Free acidity, peroxide value, UV spectrophotometric indices (K232, K270), evaluated according to the official methods described in Regulation EEC 2568/91 of the Commission of the European Union [15].

2.4. CHLOROPHYLL AND CAROTENOID

The pigment content was evaluated by measuring the absorbance at 670 nm for chlorophylls and 470 nm for carotenoids [16].

2.5. TOTAL PHENOLS

The total phenol contents of the oils were determined by the Folin-ciocalteu reagent [17]. The absorbance was measured at 725 nm. Results were expressed as mg Gallic acid equivalent/kg of oil using a calibration curve ($R^2 = 0.9947$).

2.6. CHROMATOGRAPHIC ANALYSIS OF PHENOLS BY HPLC-UV

To isolate the phenolic fraction of olive oils, we used the method described by the IOC [18]. 2 g of olive oil were weighed from each sample and added to1 ml of the internal standard solution (using syringic acid as an internal standard). 5 ml of methanol/water (80/20), the mixture was shacked for 1 minute, then centrifuged at 4000 rpm/min for 15 minutes. The methanol/water layer was separated, and the extraction repeated twice. After that, the extracts were evaporated to dryness under vacuum in the rotavapor instrument at a low temperature (less than 35°C). The residue was dissolved in 1 mL of methanol/water (1/1, v/v) and subjected to filtration with a filter for syringe. Then, analysed in a Knauer HPLC system with a column C18 (4,6 mm I.D. × 250 mm length, particle size 5 µm), and Spectrophotometric UV detector at 280 nm. The mobile phase consisted of a mixture of Solvent (A): water 0.2% H_3PO_4 (V/V) and Solvent (B): methanol /acetonitrile (50/50, V/V). The chromatograms were recorded at 280 nm using syringic acid as internal standard and identified by comparison with relative retention times of pure compounds.

Table II - Morphological characters of different varieties studied

Cultivars	Morphological characters						
	Maturity index	Fruit moisture (%)	Fruit weight (g)	Stone weight (g)	Flesh weight (g)	Flesh percentage (%)	Oil content %
Bouchouk Lafayette	3,54± 0,08 e	0,54 ±0,01d	4,08±1.12 a	0,66±0,19 a	3,42±1,19 b	82,37±7.60 b	33,27±0,04 d
Souidi	6,04± 0,02 a	0,54±0,01 d	0,59±0,12 e	0,18±0,03 f	0,41±0.12 f	67,45±10.52 d	15,49±0,01 j
Aghchren d'El Ousseur	5,18±0,03 b	0,61±0,00 b	3,34±0.98 b	0,46± 0,11 c	2,87±0.98 c	84,91±5.92 ab	46,57±0,06 a
Azeradj	2,26± 0,04 i	0,46 ±0,01 e	4,50±0,93 a	0,51±0,13bc	3,99±0.96 a	88,15±3.81 a	25,39±0,01 i
Boughenfous	2,62± 0,06 h	0,47 ±0,00 e	0,85±0,16 de	0,28±0,04 de	0,57±0.16 f	65,51±9.5 d	27,93±0,03 h
Aguenaou	3,42± 0,03 f	0,66±0,01 a	0,85±0,16 de	0,22±0,05ef	0,63±0.17 f	72,99±8.3 c	33,51±0,02 c
Aghchren de Titest	4,33 ±0,03 c	0,67±0,01 a	2,60±0,72 c	0,36±0,09 d	2,24±0,76 d	84,57±6.63 ab	33,08±0,04 e
Aberkane	3,25 ±0,07 g	0,61 ±0,00 b	4,01±1.11 a	0,56±0,11 b	3,45±1.14 b	85,13±6.56 ab	30,88±0,06 g
Limli	4,02±0,02 d	0,48 ±0,01 e	1,18±0,27 d	0,27±0,04 e	0,92±0,27 f	76,04±7.95 c	33,91±0,02 b
Sigoise	2,53± 0,04 h	0,57 ±0,00 c	2,16±0,28 c	0,49±0,10bc	1,66±0,30 e	76,75±5.52 c	31,67±0,04 e

Values are shown as Mean Standard deviation (n = 3). The results are statistically analyzed by ANOVA followed Turkey's: The mean in each column with different letters indicates a significant difference (P < 0.05)

2.7. FATTY ACIDS

The composition of fatty acids was determined by gas chromatography (GC). The fatty acids of the different samples were prepared according to the method described by the European Union Commission Regulation EEC No. 2568/91 (EEC, 2015) [19]. Methyl esters were formed by cold transesterification in a methanolic solution of potassium hydroxide. The fatty acid esters obtained were analysed using a Chrompack CP 9002 device, with detector FID (T = 250°C). The column used was a capillary column, with a length of 30 m and an internal diameter of 0.32 mm × 0.25 µm. The carrier gas was nitrogen at a flow rate of 1ml/min and the oven temperature was 200°C, and injection temperature at 250°C, a split splitless injection at 250°C.

2.8. STATISTICAL ANALYSES

All experiments were performed in triplicate; all data are expressed as the mean ± standard deviation. The statistical analysis was performed with the XLSTAT statistical software, version 2016. An analysis of variance (ANOVA) with one factor (cultivar) followed by the Tukey method at the level of 5% significance, to determine the different homogeneous groups was carried out. A Principal Component Analysis (PCA) of fatty acids was performed, with the aim of revealing associations and differences between the different cultivars.

3. RESULTS AND DISCUSSION

3.1. MORPHOLOGICAL CHARACTERS

Table II presents some agronomic parameters of the10 cultivars studied. The maturity index ranged widely from 2.26 to 6.04. The lowest maturity index was marked by the *Azeradj* variety with 2.26, while the highest maturity index was 6.04 for the *Souidi* variety. The fruits weight of different varieties (Table 2) ranged from 0.59 g (*Souidi*) to 4.50 g (*Azeradj*). *Boughenfous, Limli, Souidi, Aguenaou* have a weight fruit lower than 2 g. *Aghchren d'ElOusseur, Aghchren de Titest, Sigoise,* have intermediate mass olives ranged from 2-4 g. The highest fruit weight was recorded for the following cultivars *Azeradj* (4.50 g), *Aberkane* (4.01 g), *Bouchouk Lafayette* (4.08 g). These three cultivars are used for table olives or for a double purpose due to their size. The analysis of the variance showed a very highly significant difference ($p \leq 0.0001$) for fruit weight between cultivars. The study carried out in the centre and the east of Algeria [20] has shown lower values to our results, especially for the varieties *Bouchouk*, *Azeradj* and *Boughenfous.* Abdessemed et *al*. [21] reported close results for the *Sigoise* variety, *Aghchren de Titest*, on the other hand, very low results for *Limli*.

The water content of the different olive varieties varies between 46% (*Azeradj*) to 67% (*Aghchren de Titest*). Our results fit into the range given by Ravetti [22] that vary between 40 to 75%. It was reported [23] that a decrease in fruit moisture was proportional to an increase in oil concentration. high moisture content indicates both a lower oil and dry flesh content [24]. Regarding the oil content (table 2), the Souidi variety contains the lowest value (15.50%), while the Aghchren of el-Ousseur has the highest value (46.5709%). The analysis of the variance indicates a very highly significant difference between the cultivars tested ($p < 0.0001$). Our results are similar for those reported for Algerian varieties [25].

Table III - Physico-chemical indices of the oil of different Algerian olive varieties

Cultivars	Analytical oil parameters			
	Free acidity (% of oleic acid/kg)	Peroxide value (meq O_2/kg of oil)	Specific extinction K_{232}	Specific extinction K_{270}
Bouchouk Lafayette	0,35±0,02 cd	10,53±0,04 g	3,00±0,00 a	0,16±0,00 b
Souidi	0,38±0,02 cd	15,51±0,02 b	2,25±0,00 c	0,13±0,00 d
Aghchren d'El Ousseur	0,27±0,03 f	13,02±0,02 e	1,98±0,00 f	0,11±0,00 e
Azeradj	1,58±0,00 a	11,52±0,02 f	1,94±0,01 g	0,17±0,00 a
Boughenfous	0,41±0,00 c	6,02±0,03 i	1,42±0,01 i	0,13±0,00 d
Aguenaou	0,35±0,04 cd	14,51±0,02 d	2,05±0,01 e	0,13±0,00 d
Aghchren de Titest	0,48±0,01 b	15,01±0,01 c	2,37±0,00 b	0,13±0,00 d
Aberkane	0,31±0,01 ef	23,01±0,02 a	2,08±0,00 d	0,14±0,00 c
Limli	0,33±0,00 de	4,02±0,03 j	1,76±0,01 h	0,13±0,00 d
Sigoise	0,35±0,00 cd	7,00±0,01 h	1,17±0,01 j	0,11±0,00 e

Values are reported as Mean (n = 3). The results are statistically analyzed by ANOVA followed by Turkey's: The mean in each column with different letters indicates a significant difference (P < 0.05)

3.2. QUALITY PARAMETERS

The quality indices of different cultivars studied were presented in Table III. The free acidity of the studied samples has shown average values that oscillate from 0.31% (*Aberkane*) to 1.58% (*Azeradj*), which distinguished two distinct categories of oil (Extra virgin and virgin olive oil), according to the standards of the International Olive Council [26]. Almost all the oil samples were classified as extra virgin oils (acidity ≤ 0.8%), except for the *Azeradj* cultivar, which corresponded to the category of virgin oils (acidity ≤ 2%) with value 1.58%.Our results are very low for the oil obtained from *Limli* (0.33%) variety, compared to those reported [27], where the free acidity is 2.84% for the olive oils produced in the East of Algeria region. The analysis of the peroxide index revealed average values vary from 4.01 to 23.0 expressed in Table 3. All samples studied of olive oil have a peroxide index less than 20 meq O_2/ kg, except for the oil obtained from *Aberkane* variety with a peroxide value of 23.0 meq O_2/ kg of olive oil, which exceeds the limit (20 meq O_2/ kg) established by the IOC [26]. The minimum value was recorded in the *Limli* cultivar with a peroxide content of 4.01 meq O_2/kg. Our results are close to those found [28]; peroxide index values varied between 5.19 and 18.76 meq of O_2 / kg for Algerian and Italian varieties. Values of specific extinctions in the ultraviolet at 232 nm and 270 nm are presented on table 3. The values for the specific extinction K_{232} of the varieties studied show values that vary between 1.17 and 3.00. The nine samples studied indicate that they do not exceed the limit established by IOC [26] (≤2.5) except for *Bouchouk Lafayette* cultivar with 3.00. For the specific extinction K_{270}, the values vary from 0.11 to 0.17. However, all samples do not exceed the limit established by the IOC (≤0.22). Our results are close to those reported [29, 30].

3.3. PIGMENT CONTENT

As shown in Table 4, the pigment content is strongly influenced by the cultivar, showing very highly significant differences between samples (p < 0.0001). For chlorophylls, the lowest value was observed in the *Bouchouk Lafayette* variety with 1.71mg/kg. The highest value is recorded in the oil of the *Azeradj* variety with a value of 7.03 mg/kg.

Concerning carotenoids, the analysis of variance revealed a highly significant difference in carotenoid content between the different cultivars studied (P < 0.001), which varies between 1.22 mg/kg for *Bouchouk Lafayette* variety to 3.20 mg/kg for *Boughenfous* variety. β-carotene is a major carotenoid, which

Table IV: Pigments and total phenols content of olive oil varieties

Cultivars	Chlorophyll (mg/kg)	Caroténoïds (mg/kg)	Total phenols (mg /kg of oil)
Bouchouk Lafayette	1,71±0,23 g	1,22±0,03 h	168,83±0,01 g
Souidi	2,64±0,19 f	1,45±0,03 g	198,32±0,01 f
Aghchren d'El Ousseur	2,06±0,17 g	1,30±0,02 h	92,17±0,01 i
Azeradj	7,03±0,13 a	2,82±0,01 b	258,97 ±0,01 c
Boughenfous	4,48±0,08 c	3,20±0,06 a	435,88±0,01 a
Aguenaou	3,67±0,06 d	2,11±0,07 d	258,12±0,01 d
Aghchren de Titest	3,08±0,12 f	1,80±0,01 e	122,50±0,01 h
Aberkane	3,24±0,13 e	1,60±0,03 f	56,79± 0,01 j
Limli	5,75±0,08 b	2,61±0,05 c	205,90±0,01 e
Sigoise	2,88±0,01ef	2,56±0,04 c	357,53±0,01 b

Values are reported as Mean (n = 3). The results are statistically analyzed by ANOVA followed by Turkey's: The mean in each column with different letters indicates a significant difference (P < 0.05)

gives carotenoids a protective effect against degradation [31]. It has been noted that the content of chlorophyll and carotenoid pigments varies significantly with the variety [30]. Lower levels of chlorophylls and carotenoids was noted for Algerian varieties [32].

3.4. TOTAL PHENOLS

The results obtained (table IV) showed a very highly significant difference ($p < 0.0001$) between the studied varieties. The richest varieties are *Boughenfous and Sigoise,* with contents of 435.88 and 357.53 mg/kg, respectively. The poorest are *Aberkane and Aghchren d'El Ousseur* varieties, with 56.79 and 92.17 (mg of gallic acid/kg) respectively. Phenolic compounds contribute to the taste characteristics and high stability of virgin olive oil against oxidation [10]. Our results agree with those reported [33] for the Algerian varieties and those for varieties from Argentina [28]. On the other hand, our results are very high compared to those reported [28]; lower levels of polyphenols (from 27 to 184 mg/kg) have been noted for Algerian and Italian olive oils.

3.5. PHENOLIC PROFILES

Table V shows the quantitative composition (mg/kg) of the phenols determined by HPLC analysis. 3 phenolic compounds were identified and quantified: Hydroxytyrosol, Tyrosol and Oleocanthal (fig.1). Hydroxytyrosol and tyrosol, represent hydrolysis products of secoridoid compounds, like oleuropein and ligstroside aglycons [28]. The hydroxytyrosol content was higher in *Sigoise*, *Azeradj* and *Souidi* cultivars, while this compound was lower in other cultivars. Hydroxytyrosol is one of the major phenolic

Table V - HPLC phenolic composition of olive oil varieties.

Cultivars	Hydroxytyrosol (mg/kg VOO)	Tyrosol (mg/kg VOO)	Oleocanthal (mg/kg VOO)	Phenols (mg T/kg VOO)
Bouchouk Lafayette	4,98±0,11 c	27,98±0,06 d	nd	173,25±0,35g
Souidi	16,71±0,17 b	48,58±0,12 a	22,93±0,08 c	218,15±0,21c
Aghchren d'El Ousseur	nd	3,7±0,28 i	nd	105,17±0,23j
Azeradj	16,31±0,13 b	24,68±0,13 f	40,63±0,09 b	216,13±0,18d
Boughenfous	3,31±0,27 e	37,77±0,08 b	67,93±0,03 a	263,01±0,01a
Aguenaou	5,01±0,06 c	25,83±0,19 e	nd	205,01±0,01e
Aghchren de Titest	nd	8,62±0,11 g	nd	112,03±0,04i
Aberkane	nd	6,84±0,12 h	nd	148,01±0,01h
Limli	4,31±0,03 d	36,27±0,38 c	nd	181,05±0,07f
Sigoise	33,74±0,05 a	35,96±0,01 c	nd	253,02±0,03b

Values are reported as Mean (n = 2). The results are statistically analyzed by ANOVA followed by Tukey's: The mean in each column with different letters indicates a significant difference ($P < 0.05$), nd: not detected, T: Tyrosol.

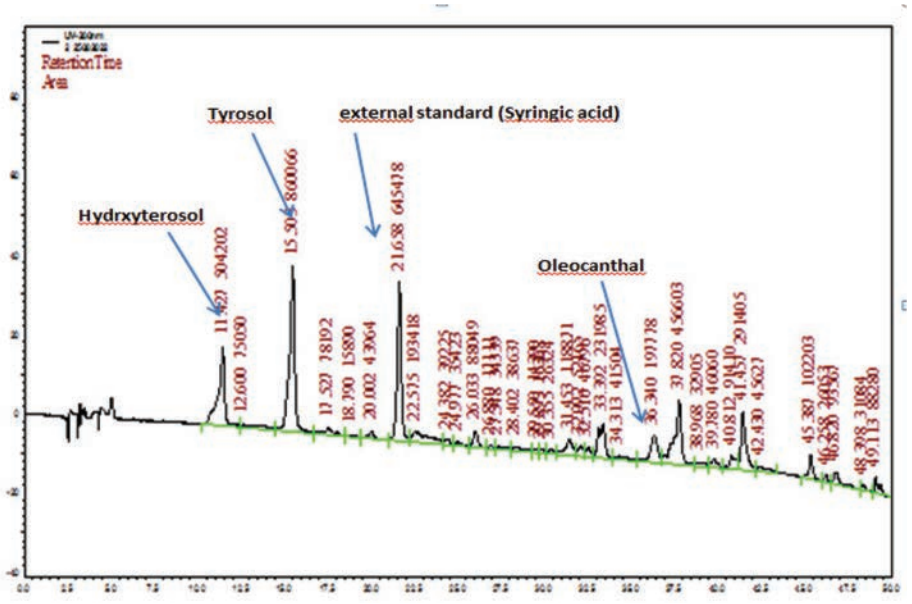

Figure 1 - HPLC chromatograms at 280 nm of phenolic extracts from olive oil and external standard peaks

Table VI - Profile of fatty acids of olive oil different Algerian varieties

Cultivars/ Fatty acids (%)	C16:0	C16:1ω 7	C17:0	C18:0	C18:1ω 9	C18:2ω 6	C18:3ω 3	C20:0	C20:1ω 9	C22:0	C22:1	C24:0	∑SFA	∑MUFA	∑PUFA	Oleic/ Linoleic	MUFA/ PUFA
Bouchouk lafayette	13,31 f	0,89 f	0,15 cd	2,60 f	61,86 j	17,70 a	0,63 g	0,48 f	0,33 ab	0,14 d	1,01 b	0,08 a	16,76 g	64,09 f	18,32 a	3,50 j	3,50 i
Souidi	13,93 e	1,04 e	0,21 a	2,70 e	66,26 g	13,79 b	0,78 e	0,47 f	0,20 f	0,14 d	0,25 h	0,00 b	17,44 d	67,75 e	14,57 b	4,80 i	4,64 h
Aghchren d'el ousseur	11,73 i	0,68 h	0,17bc	2,08 i	70,91 d	9,95 d	0,71 f	0,65 a	0,35 a	0,17bc	1,16 a	0,00 b	14,81 i	73,10bc	10,66 e	7,13 f	6,86 d
Azeradj	14,31 c	1,35 b	0,14 d	3,06 a	65,14 i	9,18 f	0,69 f	0,56 c	0,30 cd	0,15 cd	0,63 d	0,00 b	18,22 c	67,42 e	9,87 g	7,10 g	6,83 e
Boughenfous	14,17 d	1,17 c	0,17bc	2,26 g	75,14 a	4,82 j	0,75 e	0,52	0,32bc	0,21 a	0,31 g	0,00 b	17,32 e	78,44 a	5,57 j	15,59 a	13,81 a
Aguenaou	13,12 g	0,82 g	0,16bc	2,81 d	70,67 e	8,79 h	1,01 c	0,60 b	0,35 a	0,18 b	0,04 i	0,00 b	16,87 f	71,88 c	9,80 h	8,04 c	7,33 c
Aghchren de tistest	15,08 b	1,14 d	0,17bc	2,90 c	68,14 f	9,44 g	1,04 b	0,53 de	0,28 d	0,16bc	0,95 c	0,00 b	18,84 b	70,51 cd	10,48 f	7,22 e	6,73 f
Aberkane	12,41 h	0,88 f	0,18 b	2,97 b	73,37 c	7,33 i	0,98 d	0,51 e	0,29 d	0,15 cd	0,62 d	0,00 b	16,22 h	75,16 b	8,31 i	10,01 b	9,05 b
Limli	15,79 a	1,71 a	0,00 e	2,91 c	65,65 h	11,72 c	0,75 e	0,54 cd	0,25 e	0,11 e	0,40 f	0,00 b	19,34 a	68,01 de	12,47 c	5,60 h	5,45 g
Sigoise	11,18 j	0,70 h	0,00 e	2,13 h	73,47 b	9,87 e	1,11 a	0,35 g	0,33 ab	0,09 e	0,55 e	0,00 b	13,75 j	75,05 b	10,98 d	7,44 d	6,84 de

Values are reported as Mean (n=3). The results are statistically analyzed by ANOVA followed by Turkey's: The mean in each column with different letters indicates a significant difference (P <0.05), SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids

compounds in olive oil that exerts antioxidant, anti-inflammatory, anti-platelet aggregation and anti-atherogenic activities in in vitro and animal models [34]. Recently, the European Food Safety Authority (EFSA) has recognised protective effects of the olive oil phenolic compounds on LDL oxidation, in particular of HT (Commission Regulation, 2012) [35]. The claim may be used only for olive oil, containing at least 5 mg of hydroxytyrosol and its derivatives (e.g., oleuropein complex and tyrosol) per 20 g of olive oil.

The concentration of tyrosol was significantly high in all oils which are in accordance with the recent results on Algerian varieties. Similar results were noted for these two compounds in the Algerian varieties [32]. The oleocanthal content was found higher in *Boughenfous, Azeradj and Souidi cultivars,* for other varieties has not been detected. Besides, very significant differences were observed in the concentration of phenolic compounds ($p \leq 0.0001$) between the varieties studied. It was reported [36] that the phenolic profile differs between varieties of plants of the same species. Phenols are recognised as important antioxidant compounds that protect the oil against auto-oxidation, at the cellular level, against oxygen radicals [37], and contribute to its pungent and bitter taste. Hydroxytyrosol (HTyr), tyrosol (Tyr), oleacein and oleocanthal are the main compounds responsible for the beneficial effects of EVOO as part of the Mediterranean diet [38, 39].

3.6. FATTY ACIDS

The fatty acids identified and quantified are shown in table VI. In all cultivars, the main fatty acids were oleic, linoleic, palmitic, and stearic acids. Oleic acid has always been the most abundant compound, accounting for more than 60% of the total fatty acids. We note that the level of oleic acid, the major fatty acid of olive oil, is very low in *Bouchouk Lafayette* cultivar with concentration of 61.86%, although *Boughenfous* proved to be the best performing variety with the highest rate (75.15%); followed by *Sigoise* (73.48%) and *Aberkane* (73.38%).The analysis of variance showed a very highly significant difference for oleic acid between the different varieties studied ($p < 0.0001$).The fatty acid composition varies relatively due to genetic and environmental factors [40]. Our results were close to those obtained [41] on six olive oils from six cultivars of Tunisian origin. Similar results were reported for different Algerian varieties namely *Azeradj*, *Blanquette*, *Bouricha*, *Chemlal*, *Limli, Sigoise* [42].

Concerning the linoleic fatty acid (C18:2ω6), *Bouchouk Lafayette* cultivar has maximum with 17.70% against 4-15% for the other cultivars, hence the difference is very highly significant between the varieties ($p < 0.0001$). Palmitic acid was the major saturated fatty acids; it varies between 11.18% (*Sigoise*) to 15.79% (*Limli*). The analysis of the variance showed a very highly significant difference between the cultivars

tested ($p < 0.0001$). Another saturated acid is stearic acid that varies between 2.08% (*Aghchren d'ElOusseur*) to 3.06% (*Azeradj*).

The two ratios between (MUFA/PUFA) and Oleic/Linoleic are strongly influenced by the cultivar ($p < 0.0001$). *Boughenfous* recorded the highest ratio with 13.82 and followed by *Aberkane* with 9.06 against the other cultivars which vary between 3.50-8%. Furthermore, the Oleic/Linoleic ratio varies between 3.50% (*Bouchouk Lafayette*) to 15.59% (*Boughenfous*). The content of this ratio is five times more for the cultivar *Boughenfous* compared to *Bouchouk and Lafayette*. According to [29, 33] the MUFA/PUFA ratio is of great importance because of the nutritional properties and oxidative stability of olive oils. The high proportions of monounsaturated fatty acids (∑MUFA) represent one of the most important technological and nutritional characteristics of olive oils [44]. Our results are higher than those reported [45] for Tunisian varieties at different altitudes. Authors [43, 46] noted that varietal character strongly influenced fatty acid composition. The variability in our study could be explained by the genetic characters of cultivars since the culture conditions and oil extraction conditions were the same.

3.7. PRINCIPAL COMPONENTS ANALYSIS (PCA)

The principal component analysis was applied to the fatty acid profile of the different varieties, to evaluate their correlation (Figure 2a 2b, Table 6). The projection of the parameters on the factor plane F1-F2 of the PCA (Figure 2) evaluates the variability between the parameters, by their dispersion on the two axes which explain about 64.59% of the total variance. The axes 1 and 2 explain 40.33 and 24.27% of the variance, respectively.

The projection of the points on the circle indicates a good dispersion of the variables on the two axes. All the variables are well represented in this factorial plane since their correlation with the axes are relatively important, which means that the samples studied show a great chemical diversity. The projection is relatively far from the centre for some parameters. The axis 1 in the positive direction associates the following fatty acids: 22:0, C18: 1, C20: 0, C18: 3w3, C18: 1w9, Oleic acid / Linoleic acid ratio, ∑MUFA, MUFA / PUFA ratio, C20: 1w9, while the negative direction of the same axis is associates the following fatty acids: C16: 1w7, ∑SFA, C18: 0, C16: 0, ∑PUFA, C18: 2w6, C17: 0, C22:1. However, the axis 2 on the positive side is defined by saturated fatty acids (∑SFA), C16: 0, C18: 0, C16: 1w7, C20:0, C17:0, C22:0, Oleic/Linoleic, MUFA / PUFA and in the negative sense it is defined by the following fatty acids: C20: 1w9, C18: 2w6, C22:1, C18:3w3, C18:1w9, ∑MUFA, ∑PUFA.

The projection of the individual elements showed a good dispersion on the factorial plane and reveals the grouping of individual elements (figure 3). According to the F1 axis we can distinguish 5 groups or each group's varieties that have similar coordinates. In comparison between figure 2 and 3, axis 1 shows that the group1 associates the following cultivars: *Sigoise*, *Aghchren d'el- Ousseur* are on the positive side of the F1 axis indicating that they have the highest percentages in C18:1, and approximate contents in Oleic acid / Linoleic acid ratio, ∑MUFA, MUFA / PUFA ratio. According to the axis F2, group1 is located on the negative side which indicates that they have high values in C20:1w9, C18: 3w3. Group 2 represented by two varieties: *Aberkane*, *Aguenaou* according to F1 axis are located on the positive side and close to the centre of the axis and are characterised by a more homogeneous grouping according to their high oleic acid content: (C18:1w9) and the ratio (C18:1/C18:2) and MUFA/PUFA ratio and ∑MUFA, C20:0. G3 is rep-

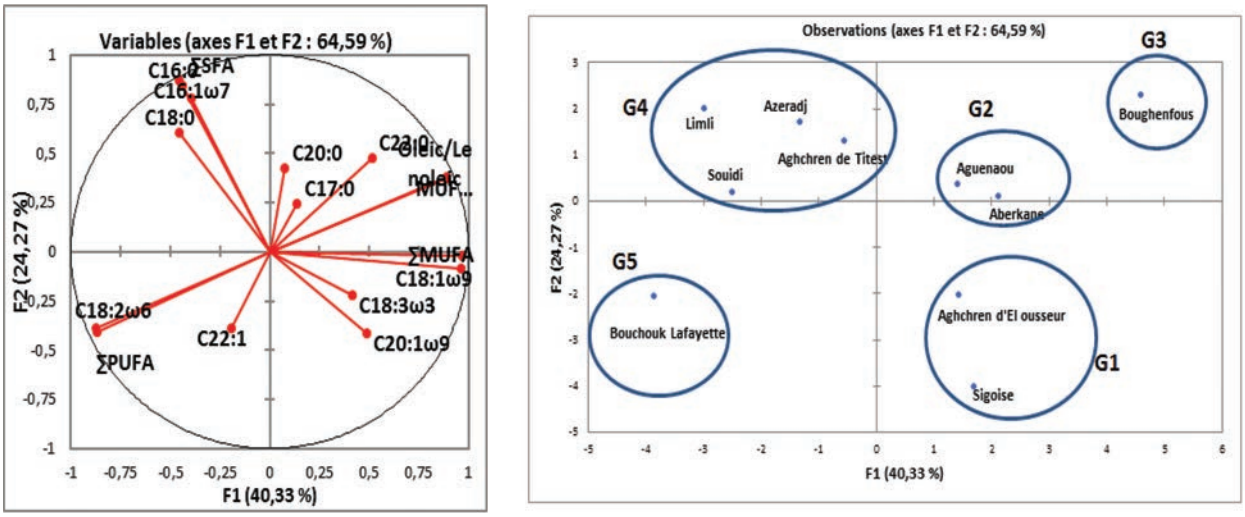

Figure 2 - a) Correlation circle of fatty acid composition and the F1 and F2 axes of the PCA

b) Representation of the results of the principal component analysis carried out for the different varieties studied.

resented by a single variety *Boughenfous* on the end of the positive portion of the F1 axis; it has the best characteristics with high value in the ∑MUFA, MUFA / PUFA ratio and oleic acid. Group 4 contains *Limli*, *Aghchren de Titest*, *Azeradj*, *Souidi*, located on the negative side of the F1 axis to their high-grade graders in saturated fatty acids (∑SFA) and C16:0, C18:0, C16:1. G5 is represented by Bouchouk Lafayette which is located on the negative side of the F2 axis having high levels of polyunsaturated fatty acids and C18: 2w6. This variety is more sensitive to oxidation. G5 is represented by Bouchouk Lafayette which is located on the negative side of the F2 axis having high levels of polyunsaturated fatty acids and C18: 2w6. This variety is more sensitive to oxidation.

4. CONCLUSION

The olive tree is one of the most important crops in Algeria. The local genetic resources of olive trees have features and performances that deserve to be valued. According to the results obtained, the varietal character influences significantly the physico-chemical parameters of virgin olive oil, including the total phenol content and fatty acids. Thus, the major fatty acids of olive oil in particular oleic acid, palmitic, stearic, and linoleic, were significantly influenced by the cultivar ($p < 0.0001$). The best result in terms of total polyphenols and oleic acid of olive oil was obtained with the *Boughenfous* variety that presented a low maturity index 2.623. The varieties with a maturity index between 2.5 and 3.5 presented the best features in minor compounds of olive oil. Globally, the results showed that the cultivar plays an important role in the quantitative and qualitative characteristics of olive oils. This characterisation must be extended to other secondary olive cultivars that remain unexplored.

Olive growers must be encouraged to promote the local olive-growing heritage by cultivating varieties approved by the National Centre for seeds and plants Control and Certification (CNCC).

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Data availability The datasets generated and analysed for this study are available from the corresponding author upon reasonable request.

Declaration

Conflict of interest The authors declare that they have no conflicts of interest.

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