Effect of geographical and edaphic factors on the quality of some olive oils from different varieties of olives grown in western Algeria

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In this study, our objective was to investigate the effect of soil and altitude on the quality of some olive oils from different varieties of olive trees. The quality parameters, the chemical composition of the oils in fatty acids, as well as the profile in phenolic compounds by HPLC are determined and soil analyses are carried out. Statistical analysis of the data was performed using multivariate analysis (PCA). The results obtained showed that the highest concentrations of oleuropein derivatives and ligstroside derivatives were observed in chemlal oil (SBA) and the recorded values were 105.97 mg/Kg and 83.49 mg/Kg. Oleocanthal was found in all the tested samples, and it was higher in Chemlal oil (102.43 mg/kg). Phenolic compounds have affinities with soil clay content and altitude, palmitic and palmitoleic acids are influenced by organic matter content and soil pH.
Key words: Algerian varieties, olive oil, quality, altitude, soil.

1. INTRODUCTION

More than 75% of the worldwide olive oil production is concentrated in the Mediterranean area [15]. Among the sectors having benefited from financial and technical support, in Algeria there is an olive growth that currently represents 4% of the useful agricultural area and 40% of the total arboreal area [16]. Olive oil production was the highest during the last fifteen years, reaching over 900,000 hl across the country, with more than 25% of the previous season production [17]. Algeria, one of the main producers of olive oil in the world (9th in the world ranking), has a wide range of varieties with two dominant ones: *Chemlal* and *Sigoise* [15]. Olive oil is a natural product known for its virtues and health benefits; it is composed of 99% fatty acids and 1% of the minor fraction (antioxidants). Olive oil healthy properties are well known in the Mediterranean diet [21]. The quality of olive oil begins at the time of planting of a particular variety, continues through the cultivation of the olive tree, the harvesting methods and duration, preliminary work, and the duration of storage at the olive grove, the transport conditions of the fruit to the unit, the storage duration before transformation and the technological management of extraction, as well as the conditions of storage and distribution of the oil. The fine composition of an olive oil, besides being strongly dependent on the cultivar used for its production, is influenced by several other factors like climate, soil conditions and agricultural practices [11]. Moreover, it is widely known that the quality of virgin olive oil is influenced by various agronomic factors, such as olive cultivar, climatic conditions, production process, and the degree of maturation and agronomic practices related to irrigation [18]. The production of olive oil is slowly moving beyond Mediterranean countries, and olive trees (*Olea europaea L.*) are being planted in countries such as Chile and New Zealand. This expansion, which is primarily due to new agricultural practices devised by

farmers to increase the olive oil yield without a loss of sensory and nutritional properties, is based on the adaptation of cultivars to climates associated with latitudes and altitudes different from their autochthonous regions [14].
Many research works are dedicated to the study of the influence of these different factors on the phenolic fraction of olive oil. Other studies have focused on determining the phenolic compound profile of virgin olive oil by various analytical techniques, in particular by HPLC. This research work was carried out to investigate the effect of soil composition and altitude on the quality of seven olive oils from different varieties of olives namely Chemlal, Sigoise and Oleaster in western Algeria.

2. MATERIALS AND METHODS

2.1 MATERIALS

Two dominant varieties in the west of Algeria, namely *Sigoise* and *Chemlal* and a wild variety *Oleaster*, are the subject of this study. Seven olive samples were collected by hand during the month of December 2016 in the regions of Zenata, Bordj Arima, Bensekrane, Sidi Belabbes (SBA), Sebra and Sig. The quantities of olive harvested are approximately 20 Kg for each sample. After harvesting fruits were quickly transported in plastic crates for oil extraction (Figure 1).
The olive oils *Chemlal* Zenata, *Chemlal* Bordj Arima and *Chemlal* Sidi Belabbes were extracted by the

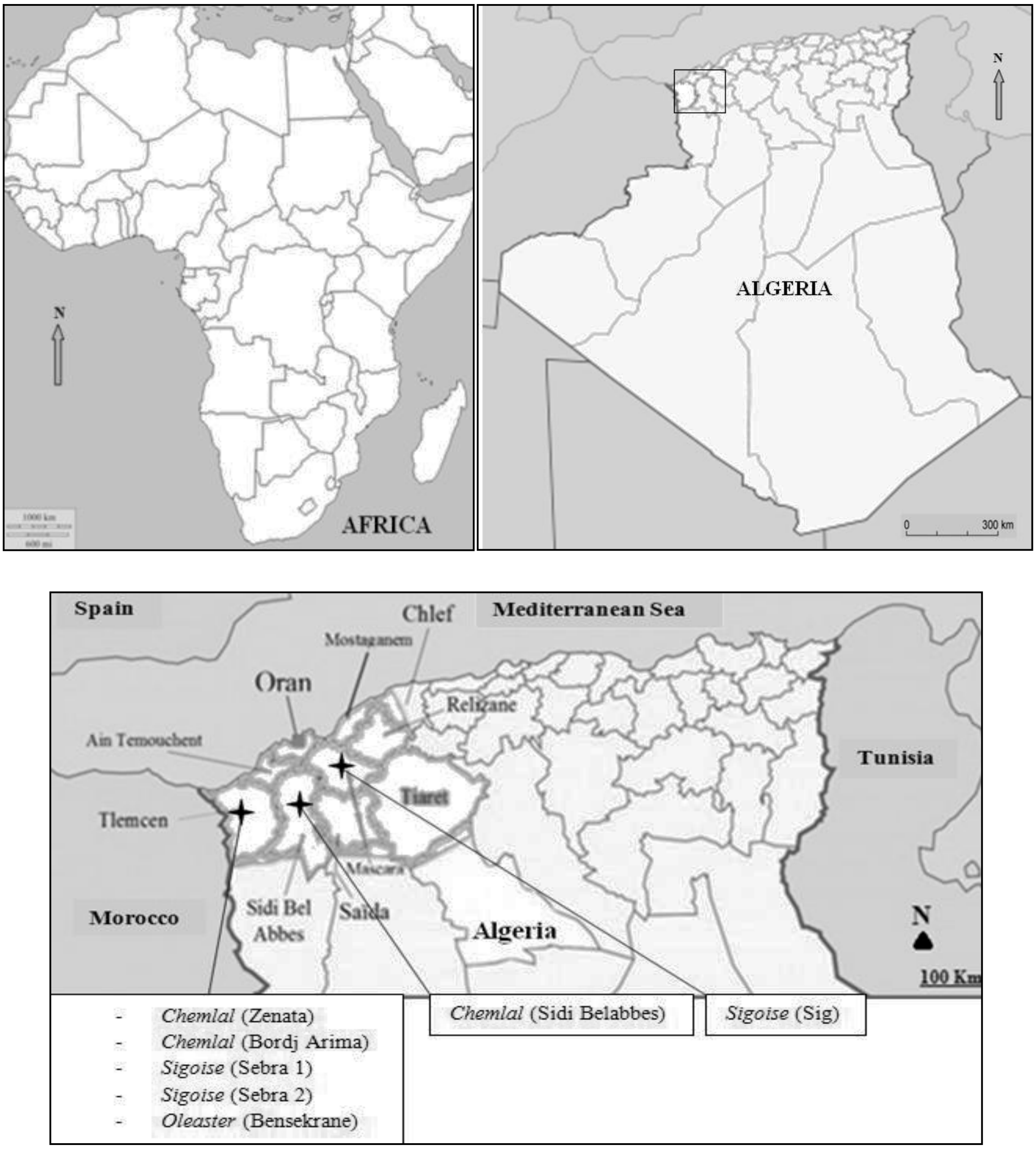

Figure 1 - Geographical location of the regions of study in Algeria

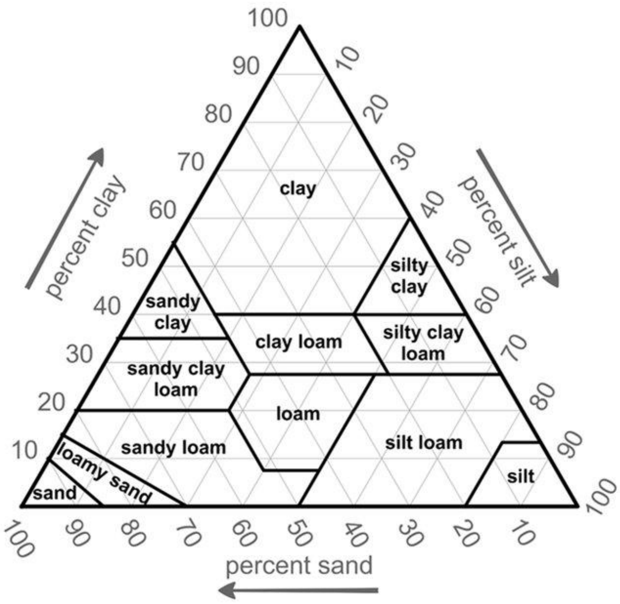

Figure 2 - USDA Soil Texture Triangle

continuous three-phase system while the olive oils *Oleaster* Bensekrane, *Sigoise* Sebra 1, *Sigoise* Sebra 2 and *Sigoise* Sig are extracted by the batch system by super press. The oils are collected in smoked glass bottles, filled, labelled and stored at a temperature of 4°C while waiting to be analysed.

2.2. QUALITY INDICES DETERMINATION

The determination of the free fatty acids, peroxide value (PV) and the UV absorption characteristics at 232 nm and 270 nm (K_{232} and K_{270}, respectively) of virgin olive oil were carried out following the analytical methods described in the European Union Commission (EEC/2568/91) [28].

2.3 TOCOPHEROL ANALYSIS

Tocopherols were analysed using a HPLC according to the method developed by Rovellini *et al* [27]. 500 mg of oil was dissolved in 10 ml of acetone. 20 µl of this solution was injected. A Column Allsphere ODS2 (Alltech) (250 mm × 4,6 mm, i.d. 4 mm) with a particle size of 5 µm and UV detectors at 292 nm were used. The mobile phase was acetonitrile/methanol (50/50) with a flow rate of 1.3 ml/min.

2.4 FATTY ACID ANALYSIS

The fatty acid composition was determined as methyl ester derivatives by gas chromatography according to methods described in EC methods [10]. Fatty acid methyl esters were prepared by vigorous shaking of a solution of each olive oil sample in n-hexane (0.5 g in 5 mL) with 0.5 mL of 2 N methanolic potassium hydroxide solution. Chromatographic analysis was performed on a CHROMPACK C 9002 gas chromatograph equipped with a FID detector, using a capillary column DB 23 (30m × 0.32mm i.d. × 0.25 µm film thicknesses). The injector and detector temperatures were maintained at 250°C; the oven temperature was set at 200°C. Nitrogen was employed as a carrier gas with a flow rate of 1 mL/min.

2.5 ANALYSIS OF THE PHENOLIC COMPOUND

The extraction of the minor polar compounds of phenolic compounds was made from 2 g of olive oil by methanol/water (80/20) solution. Identification and quantification were performed using an HPLC equipped with UV detector (λ 280 nm). A volume of 20 µl of sample was injected into a Spherisorb ODS-2 C18 column (4.6 mm × 250 mm, particle size: 5 µm). The mobile phase is composed of water/orthophosphoric acid (99.8/0.2, v/v), methanol and acetonitrile. The contents of the total and individual polyphenols are expressed in mg/kg. The internal standard is syringic acid [26].

2.6 SOIL ANALYSIS

This part begins the physico-chemical analyses of the soils of the seven olive groves where we have to collect our samples of olives, the parameters taken into consideration are: Texture, pH, total limestone and organic matter.

To carry out soil analyses, we took samples from each olive grove taking into account: sampling equipment, timing of sampling, location, depth and Conditioning of samples. After drying the samples of soils, we sieved manually using a 2 mm opening sieve, we recovered the elements passing through the sieve and that are said to be fine earth, useful for carrying out the analyses.

The purpose of the granulometric analysis is to determine the texture of the soil, the sand, and the clay, and silt content was evaluated. For this we used the Casagrande method which is based on the phenomenon of variation over time of the density of the

"soil-water" mixture measured using a hydrometer; then we used the triangle of textures (Figure 2) which allows us to determine the textural class of the soil.
The measurement of the reaction of the soil (acidity; basicity) was done using a pH meter. Among the chemicals that go into the composition of the soil, limestone plays an essential role not only in plant nutrition but also in pedogenesis. In this analysis, we used Bernard calcimeter, which allows us to measure the volume of (CO_2) released by the action of hydrochloric acid (Hcl) on the calcium carbonate ($CaCO_3$) of a sample and to measure the scale total.
$\%CaCO_3$ = (p*V)/(P*v)*100. Let v be the volume of CO_2 released by the $CaCO_3$ outlet p and V the volume of CO_2 released by the earth outlet P
For the determination of organic carbon, we used the method of Tjurin [25], which consists in knowing the quantity of potassium dichromate that will oxidise the carbon of the organic matter in the presence of sulfuric acid. The percentage of (Co) is calculated by the formula:
%Cox = [(40-d*f)*0,3/g]*100
- % Cox: percentage of carbon oxidised;
- 0,3: convert to mg;
- 40 ml: potassium dichromate 0,1M;
- d: volume of Mohr salt solution;
- f = 40% a;
- a: titration of the control solution containing only $K_2Cr_2O_7$.

To pass from the carbon rate to the total organic matter rate, the Welte coefficient is used:
% humus = %Cox*1,72

2.7 DATA ANALYSIS BY PCA
The PCA provides a graphical representation of the similarities and differences between the data in the space defined by the main components. A statistical study was carried out on all the parameters studied, to understand the results and highlight the relationships between soil parameters, altitude, and the quality of olive oil. (PCA) was applied to the dataset using TANAGRA 2.0 software.

3. RESULTS AND DISCUSSION

3.1 QUALITY INDICES
In the absence of the results of sensory analysis of the oils and according to IOC standards, the values of the quality indices (see appendix), correspond to those of the "extra virgin" category for olive oils. Chemlal Zenata, Chemlal Bordj Arima and Chemlal SBA and the "virgin" category for Sigoise Sebra 1, Sigoise Sig and Oleaster Bensekrane olive oils. As well as the "ordinary" category for Sigoise Sebra 2 oil.
The peroxide value and acidity of studied olive oil were in the ranges of 6,60-14,60 meq of O_2/Kg and 0,6-2,8 (% oleic acid), respectively. K_{270} was between 0,20 and 0,13 and K_{232} was in the range of 1,873 to 2,429.

3.2. TOCOPHEROLS
Indeed, the seven oils studied have a fairly high percentage of alpha tocopherol, the highest rate is in *Chemlal* oil SBA with 228,12 mg/Kg, followed by *Sigoise* oil Sebra 2 and *Oleaster* Bensekrane 202,9 and 201,71 mg/Kg respectively. While the oils *Chemlal* Bordj Arima, *Chemlal* Zenata and *Sigoise* Sig display rates of 193,55, 179,72 and 156,36 mg/Kg respectively. *Sigoise* oil Sebra 1 registers the low value which is 108,77 mg/Kg (Table I).
These results are in agreement with several studies which indicate that the tocopherol content is highly dependent on the variety [12-7]. According to Alasalvar *et al* [1], the proportion of tocopherols is a function of several factors such as the nature of the oil, geographical origin, culture, and climate.

3.3. COMPOSITION OF FATTY ACIDS
The analysis of the composition of fatty acids (Table II) is qualitatively similar between the samples. Quantitatively, all the oils studied have different fatty acid contents that meet the standards established by the IOC [4]. Oleic acid (C18: 1) is the dominant fatty acid, all the oils studied have proportions greater than 60%. The highest values are recorded respectively for *Oleaster* oil Bensekrane, *Sigoise* Sebra 1, *Chemlal* Bordj Arima and *Chemlal* Zenata 72,80%, 72,26%, 70,41% and 70,31% followed by other oils, the lowest value being noted for *Chemlal* oil SBA 67,78%.
The percentages of linoleic acid (C18: 2) vary between 10,24% for *Oleaster* oil Bensekrane and 12,23% for *Sigoise* Sig. While the palmitic (C16: 0) and stearic (C18: 0) acid levels vary between 11,30% for *Sigoise* oil Sebra 1 and 15,86% for *Chemlal* SBA and 2,29% for *Chemlal* oil SBA and 3.96% for *Sigoise* Sig respectively. *Oleaster* oil Bensekrane has the highest

Table I - Tocopherol content (mg/kg) of different olive oils

Olive oils	*Chemlal* Zenata	*Sigoise* Sig	*Sigoise* Sebra 2	*Chemlal* SBA	*Sigoise* Sebra 1	*Oleaster* Bensekrane	*Chemlal* Bordj Arima
Delta Tocopherol	0,56±0,13	0,51±0,02	0,69±0,09	0,58±0,13	0,35±0,06	0,49±0,04	0,57±0,09
Gamma Tocopherol	7,11±0,06	5,8±0,49	8,86±0,2	9,29±0,33	5,86±0,14	11,33±0,14	6,58±0,49
Beta Tocopherol	1,18±0,05	1,69±0,09	3,16±0,27	2,11±0,22	1,37±0,17	1,98±0,26	1,65±0,11
Alfa Tocopherol	179,72±1,67	156,36±1,27	202,9±2,74	228,12±1,58	108,77±1,77	201,71±4,95	193,55±1,97
Total Tocopherols	188,55±1,8	164,35±1,66	215,6±2,89	240,1±1,60	116,35±2,14	215,49±7,37	202,35±1,47

Means ± standard deviation (n = 3)

Table II - Fatty acid compositions (%) of the different oils

Fatty acids (%)	*Chemlal* Zenata	*Sigoise* Sig	*Sigoise* Sebra 2	*Chemlal* SBA	*Sigoise* Sebra 1	*Oleaster* Bensekrane	*Chemlal* Bordj Arima
C14 : 0	0.02 ± 0,0	0.02 ± 0,0	0.03 ± 0,0	0.02 ± 0,0	0.03 ± 0,0	0.02 ± 0,0	0.02 ± 0,0
C16 : 0	12.81 ± 0,30	12.09 ± 0,01	14.54 ± 0,04	15.86 ± 0,05	11.30 ± 0,03	11.55 ± 0,08	12.09 ± 0,07
C17 : 0	0.05 ± 0,0	0.04 ± 0,01	0.05 ± 0,0	0.04 ± 0,0	0.04 ± 0,0	0.04 ± 0,0	0.04 ± 0,0
C18 : 0	2.58 ± 0,02	2.80 ± 0,27	2.95 ± 0,06	2.29 ± 0,02	2.83 ± 0,16	2.51 ± 0,02	2.80 ± 0,02
C20 : 0	0.34 ± 0,01	0.36 ± 0,02	0.35 ± 0,02	0.34 ± 0,01	0.32 ± 0,01	0.32 ± 0,01	0.36 ± 0,01
C22 : 0	0.09 ± 0,01	0.09 ± 0,01	0.11 ± 0,01	0.06 ± 0,05	0.08 ± 0,01	0.08 ± 0,0	0.09 ± 0,0
C24 : 0	0.04 ± 0,0	0.04 ± 0,01	0.05 ± 0,01	0.04 ± 0,01	0.04 ± 0,0	0.04 ± 0,01	0.04 ± 0,01
SFA	15.93 ± 0,05	15.44 ± 0,05	18.08 ± 0,02	18.65 ± 0,02	14.64 ±0,03	14.56 ± 0,02	15.44 ± 0,02
C16 : 1	1.41 ± 0,07	1.21 ± 0,06	1.76 ± 0,01	2.11 ± 0,02	1.01 ± 0,0	1.16 ± 0,0	1.21 ± 0,02
C17 : 1	0.08 ± 0,0	0.06 ± 0,02	0.08 ± 0,01	0.09 ± 0,01	0.06 ± 0,0	0.07 ± 0,01	0.06 ± 0,01
C18 : 1	70.31 ± 0,37	70.41 ± 0,07	68.04 ± 0,17	67.78 ± 0,06	72.26 ± 0,29	72.80 ± 0,05	70.41 ± 0,07
C20 : 1	0.28 ± 0,01	0.30 ± 0,01	0.28 ± 0,01	0.25 ± 0,01	0.31 ± 0,01	0.28 ± 0,01	0.30 ± 0,0
MUFA	72.08 ± 0,11	71.98 ± 0,04	70.16 ± 0,05	70.23 ±0,03	73.64 ± 0,08	74.31 ± 0,02	71.98 ± 0,03
C18 : 2	11.21 ± 0,01	11.66 ± 0,08	10.96 ± 0,06	10.34 ± 0,02	10.86 ± 0,06	10.24 ± 0,0	11.66 ± 0,02
C18 : 3	0.81 ± 0,01	0.87 ± 0,02	0.82 ± 0,01	0.75 ± 0,0	0.88 ± 0,01	0.93 ± 0,01	0.87 ± 0,0
PUFA	12.02 ± 0,01	12.53 ± 0,05	11.78 ± 0,04	11.09 ± 0,01	11.74 ± 0,06	11.17 ± 0,01	12.53 ± 0,01
C18 : 1/C18 : 2	6.27 ± 0,36	6.03 ± 0,01	6.2 ± 0,11	6.55 ± 0,04	6.65 ± 0,23	7.1 ± 0,05	6.03 ± 0,02

Means ± standard deviation (n = 3)

oleic acid / linoleic acid ratio 7,1 and the lowest remains for *Sigoise* oil Sig 5,67.

The levels of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) vary depending on the oils and variety, the oils *Chemlal* SBA and *Sigoise* Sebra 2 have a percentage of acids saturated fat of 18,65% and 18.08% respectively, of monounsaturated fatty acids of 70,23% and 70,16% and of polyunsaturated fatty acids of 11,09% and 11,78%. While the oils *Sigoise* Sig, *Chemlal* Zenata, *Chemlal* Bordj Arima, *Sigoise* Sebra 1 and *Oleaster* Bensekrane record respectively a total of saturated fatty acids of 15,96, 15,93, 15,44, 14,64 and 14,56%, 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%.

3.4. DETERMINATION OF PHENOLIC COMPOUND BY (HPLC)

The quantitative data concerning the phenolic content of the seven samples are given in (Table III). Five main phenolic groups have been detected: phenolic alcohols (hydroxytyrosol and tyrosol), secoiridoids (Mainly derived from oleuropein and ligstroside and elenolic acid), Lignans, flavonoids (luteolin and apigenin) and phenolic acids. The results relating to the content of total phenolic compounds in olive oils are shown in (Table III). The contents are between 93,32 mg/Kg for *Sigoise* oil Sig and 328,99 mg/Kg for *Chemlal* oil SBA, while the oils *Chemlal* Zenata, *Sigoise* Sebra 1 and *Chemlal* Bordj Arima display the values of 216,64, 191,3 and 188,49 mg/Kg respectively. The oils *Sigoise* Sebra 2 and *Oleaster* Bensekrane record rates of 169,56 and 141,68 mg/Kg. The significant difference noted between the polyphenol contents of the oils *Chemlal* SBA, *Chemlal* Zenata and *Chemlal* Bordj Arima, is explained by the difference in the region of olive production. The work of Essalami *et al* [20] has shown that the virgin olive oil obtained from the (*Roghiani*) cultivar from different regions of northern Libya shows a variation in its phytochemical contents and antioxidant properties. Other research has shown that the profile of phenolic compounds is also affected by the geographical origin of the variety of olive oil [2]. It is influenced by genotyping and other agro-climatic parameters [19].

For phenolic alcohols their quantity varies between 38,31 mg/Kg for *Sigoise* oil Sebra 1 and 7,01 mg/Kg for *Chemlal* Bensekrane. Hydroxytyrosol (3,4-DHPEA) and tyrosol (p-HPEA) are the main phenolic alcohols present in the oils studied. The Secoiridoide derivatives, mainly represented by oleuropeine and ligstroside derivatives, were the most abundant group of phenolic compounds in all the samples analysed, whatever their geographical origin and variety. In our case, the highest concentrations of oleuropein derivatives were observed in *Chemlal* oil SBA with 105,97 mg/Kg followed by *Chemlal* Zenata, *Sigoise* Sebra 1 and *Chemlal* Bordj Arima with 89,6, 87,48 and 60,08 mg/Kg respectively. While the lowest concentration is recorded by *Sigoise* oil Sig with 32,85 mg/Kg. As for ligstroside derivatives, the oils *Sigoise* Sig, *Sigoise* Sebra 2 and *Oleaster* Bensekrane record the lowest values 41,43, 44,78 and 54,97 mg/Kg respectively. While the highest value remains for *Chemlal* oil SBA in suite come the oils *Chemlal* Bordj Arima, *Chemlal* Zenata and *Sigoise* Sebra 1 with 83,49, 79,13 and 64,66 mg/Kg respectively.

The content of elenolic acid varies between 5 mg/Kg for *Sigoise* oil Sig and 42 mg/Kg for *Chemlal* Bordj Arima. In addition, another secoiridooid acid, name-

ly decarboxymethylelenolic acid, ranging from 1,56 mg/Kg for *Sigoise* Sig to 10,39 mg/Kg for *Chemlal* Zenata. The seven samples studied contain oleocanthal, found a considerable amount in *Chemlal* oil SBA 102,43 mg/Kg the lowest values were recorded by the oils *Sigoise* Sebra 2 and *Sigoise* Sig 13,26 mg/kg and 14,03 mg/Kg respectively. The amount of lignans varies between 6,48 mg/Kg for *Sigoise* oil Sig and 35,93 mg/Kg for *Chemlal* oil SBA followed by *Sigoise* oils Sebra 1, *Chemlal* Bordj Arima and *Chemlal* Zenata with contents of 25,91, 25,39 and 24,97 mg/Kg respectively, remainder *Sigoise* oil Sebra 2 with 20,06 mg/Kg and *Oleaster* Bensekrane with 17,65 mg/Kg.
Besides, flavonoids were in the range of 3,91 to 15,6 mg/Kg detected in the oils *Sigoise* Sig and *Chemlal* SBA respectively. Luteolin and apigenin were the most relevant compounds in this group. Luteolin, the most abundant flavonoid in the samples analysed, varies from 2,45 mg/Kg for *Sigoise* Sig to 10,16 mg/Kg for *Chemlal* SBA, while the concentrations of apigenin vary between 1,46 mg/Kg for *Sigoise* Sig and 5,44 mg/Kg for *Chemlal* SBA. Regarding phenolic acids, the oils studied have shown quantities of phenolic acids which vary between 2,12 mg/Kg for *Sigoise* Sig and 4,35 mg/kg *Oleaster* Bensekrane, except *Sigoise* oil Sebra 2 which records in quantity acceptable from 16,97 mg/Kg.

3.5 SOIL ANALYSIS RESULTS

Concerning the texture of the soils of the different olive groves (Table IV) and based on the triangle of textures (Figure 2), it appears that the soils of the olive groves Sebra 1, Sebra 2 and Sig are of silty texture, while the soils of olive groves Zenata and SBA have a silty-clay texture. However, the olive grove Bensekrane has a silty-clay-sandy texture and the latest olive grove Bordj Arima has a sandy-silty texture.
Regarding the pH, all soils have an alkaline pH, except the pH of the olive grove Bensekrane which is neutral. The load in ($CaCO_3$%) was estimated to be an average for most soils except for the soils of olive groves Sebra 1, Sebra2 and SBA which have a high load. Finally, organic matter was estimated to be high for the soils of olive groves Bensekrane and SBA and medium for the olive groves Sebra1 and Sebra2. While it is estimated to be very low for the olive groves Zenata and Bordj Arima and low for the olive grove Sig.
The olive tree grows poorly on clay soils because of the suffocation suffered by the roots during the rainy seasons. The harmful consequences of such a soil can be summed up in a significant drop in fruit and a reduced size of the olives, which affects the quality and yield of the oil extracted. Unlike clay soils, deep soils adapt much better to the olive tree by their ac-

Table III - Content of phenolic compound (mg/kg) of olive oils by HPLC

Phenolic compounds	*Chemlal* Zenata	*Sigoise* Sig	*Sigoise* Sebra 2	*Chemlal* SBA	*Sigoise* Sebra 1	*Oleaster* Bensekrane	*Chemlal* Bordj Arima
Total Flavonoids	8,44 ± 0,18	3,91 ± 0,64	11,58 ± 0, 22	15,6 ± 0,01	4,86 ± 0,04	13,33 ± 0,01	6,97 ± 0,01
Apigenin	2,75 ± 0,16	1,46 ± 0,38	4,53 ± 0,09	5,44 ± 0,01	1,72 ± 0,0	3,8 ± 0,04	2,03 ± 0,01
Luteolin	5,69 ± 0,02	2,45 ± 0,26	7,05 ± 0,15	10,16 ± 0,01	3,14 ± 0,04	9,53 ± 0,04	4,94 ± 0,01
Oleuropein derivatives	89,6 ± 2,87	32,85 ± 0,6	48,6 ± 0,72	105,97 ± 0,03	87,48 ± 0,2	34,37 ± 0,33	60,08 ± 0,08
Hydroxytyrosol	12,32 ± 0,19	2,47 ± 0,09	5,28 ± 0,09	2,51 ± 0,03	22,42 ± 0,11	1,07 ± 0,03	3,75 ± 0,03
Tyrosol	9,17 ± 0,06	4,99 ± 0,04	9,68 ± 0,11	6,44 ± 0,03	15,89 ± 0,06	5,94 ± 0,07	9,48 ± 0,01
Oleuropein	0,16 ± 0,01	1,11 ± 0,07	1,66 ± 0,14	0,06 ± 0,0	0,77 ± 0,07	0,24 ± 0,08	0,11 ± 0,02
Ligstroside derivatives	79,13 ± 1,95	41,43 ± 0,17	44,78 ± 0,05	147,56 ± 0,35	64,66 ± 0,32	54,97 ± 0,03	3,49 ± 0,1
Oleocanthal	42,76 ± 0,9	14,03 ± 0,02	13,26 ± 0,06	102,43 ± 0,3	23,69 ± 0,13	24,43 ± 0,09	40,93 ± 0,01
Total secoiridoid Acids	39,18 ± 0,26	6,8 ± 0,01	22,68 ± 0,23	24,93 ± 0,1	30,19 ± 0,23	18,29 ± 0,1	49,72 ± 0,11
Decarboxymethylel enolic acid	10,39 ± 0,12	1,56 ± 0,01	5,82 ± 0,08	2,63 ± 0,02	6,48 ± 0,1	2,74 ± 0,02	7,72 ± 0,01
Elenolic acid	28,79 ± 0,14	5,24 ± 0,02	1,86 ± 0,15	22,3 ± 0,08	23,71 ± 0,13	15,55 ± 0,08	42 ± 0,08
Total Lignans	24,97 ± 0,36	6,48 ± 0,01	25,91 ± 0,29	35,93 ± 0,18	20,06 ± 0,13	17,65 ± 0,01	25,39 ± 0,08
Total Phenolic Acids	2,2 ± 0,03	2,12 ± 0,04	16,97 ± 0,14	3,35 ± 0,06	3,45 ± 0,08	4,35 ± 0,06	3,53 ± 0,01
Total Biophenols	216,64 ± 4,57	93,32 ± 0,13	169,56 ± 0,5	328,99 ± 0,64	191,3 ± 0,63	141,68 ± 0,33	188,49 ± 0,38
Total Aromatic Alcohols	21,49 ± 0,25	7,46 ± 0,05	14,95 ± 0,19	8,95 ± 0,01	38,31 ± 0,17	7,01 ± 0,04	13,23 ± 0,04
Total Natural Biophenoles	204,33 ± 4,97	86,77 ± 0,11	147,85 ± 2,06	308,4 ± 0,62	180,49 ± 0,5	124,67 ± 0,24	179,45 ± 0,11
Biophenols oxidized	12,31 ± 0,40	6,55 ± 0,02	21,71 ± 0,44	20,59 ± 0,02	10,83 ± 0,13	17,01 ± 0,09	9,04 ± 0,27

Means ± standard deviation (n = 3)

Table IV - Results of soil analyzes of the olive groves used in the study in Algeria

Granulometry %	Olive grove Sabra 1	Olive grove Sabra 2	Olive grove Zenata	Olive grove Bordj Arima	Olive grove Bensekrane	Olive grove SBA	Olive grove Sig
Sand	32	37	23	37	49	28	31,5
Silt	42	40	40	25	27	40	37,5
Clay	26	23	37	23	29	32	14,5
Texture	silty	silty	silty clay	sand silty	silty-clay-sand	silty clay	silty
pH	7,60	7,51	7,70	7,39	7,40	8,89	8
Appreciation	alkaline	alkaline	alkaline	neutral	neutral	very alkaline	alkaline
$CaCO_3$ %	28	37	11,73	3	13	24	20,27
$CaCO_3$ Charge	strong	strong	average	average	average	strong	average
Organic matter %	2,56	2,96	0,4	1	3,48	5,16	1,94
Estimate	average	average	very low	Very low	strong	strong	low
Altitude (m)	593	533	207	730	295	483	50

tion of retention of rainwater which will be exhausted by the tree during the spring to feed its vegetation, which improves the oil yield and quality [13]. As far as texture is concerned, the most suitable soils for the olive tree are those characterised by a balance between sand, silt and clay (Table V).

The predominantly sandy soils have a low capacity for retaining water and minerals but allow good aeration of the soil and constitute an advantage for the olive tree when water is available, provided that relevant fertilisation is ensured to satisfy nutritional requirements of mineral elements. The amounts of clay should not be excessive as they could constitute an obstacle to the circulation of air and the conduct of the soil.

The particles must form glomerulus structures to give a certain porosity to the soil, which is possible if the soil contains enough organic matter and if a rational soil management is carried out to avoid the phenomena of compaction or erosion.

Regarding the chemical properties, it should be noted that the olive tree tolerates a good pH margin. However, attention should be paid to acidic soils with pH levels below 6.5. Based on (Table V), it is judged that the soil of the olive grove Bensekrane is the most suitable for olive growing.

Table V - Characteristics of a soil deemed suitable for olive growing [5]

Texture	Sand 20-75%
	Silt 5-35%
	Clay 5-35%
Structure	Friable
Water retention capacity	30 - 60 %
Permeability	10 - 100 mm/h
pH	7-8
Organic matter	> 1%
Nitrogen	> 0,10 %
Phosphorus available (P_2O_5)	5 - 35 ppm
Exchangeable potassium (K_2O)	50 - 150 ppm
Exchangeable Calcium ($CaCO_3$) CO_3	1 650 - 5 000 ppm
Exchangeable Magnesium	10 - 200 ppm

3.6 INFLUENCE OF SOIL AND ALTITUDE ON THE QUALITY OF OLIVE OIL

The analysis in Principal Components (PCA) (Figure 3), is established from thirty-eight measured variables and seven individual, axis 1 (PC1, 35,86%) and axis 2 (PC2, 22,89%) carries 58,75% information from the datasets, we will therefore focus on these two dimensions for interpretation.

The circle of correlation of the variables in the plane of the main components PC1 and PC2 revealed that the first group of phenolic compounds (total biophenols, natural biophenols, ligstrosides, lignans, oleuropein derivatives, secoiridoides and oleocanthal) was in affinities with a parameter soil which is clay and the geographical parameter which is the altitude of olive groves. The second group composed of flavonoids, tocopherols, palmitic acid, palmitoleic acid, heptadecenoic acid, was in affinities with the level of organic matter in the soil and their pH, next to this group distinguish phenolic acids and lignoceric acids which have an affinity with the level of limestone in the soil.

While aromatic alcohols hydroxytyrosol and tyrosol, oleic acid (C18: 1), linoleic acid (C18: 2), gadoleic acid (C20: 1) and peroxide value (PV) were not related to soil and altitude factors. However fatty acids (C18: 0 (stearic acid), C18: 2 (linoleic acid), C14: 0 (myristic acid), C17: 0 (heptadecanoic acid), C20: 0 (arachidic acid), C22: 0 (acid behenic) with acidity, UV absorbance (K_{270}) and oleuropein level, were negatively correlated with soil parameters and altitude. According to Demnati [8], the soil nature and composition and the pH influence the quality of the oil. So, fatty soils produce fewer aromatic oils than lean soils, and oils from calcareous soils have a lower acidity than those from clay soils. Olive oil was affected by altitude, especially its fatty acid composition and the polyphenol content.

Our results agree with those of Romero *et al* [14], who worked on the influence of soil, climate, and geographic origin on the phenolic compounds of Chil-

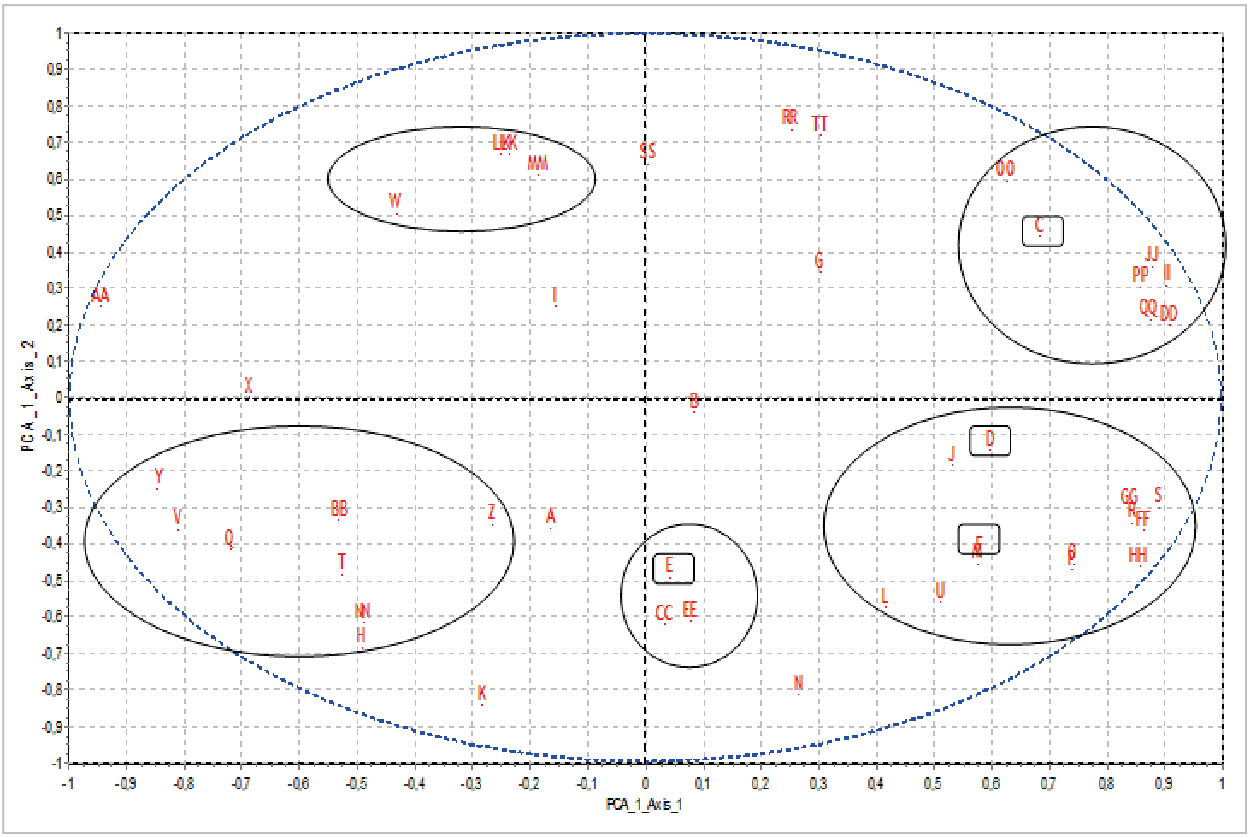

Figure 3 - Correlation circle of the variables in the main component plane PC1 and PC2

Legends :
sand: A, silt: B, clay: C, pH: D, limestone: E, organic matter: F, Altitude: G, acidity: H, PV: I, K_{232}: J, K_{270}: K, delta tocopherol: L, gamma tocopherol: M, beta tocopherol: N, alpha tocopherol: O, total tocopherol: P, C14: O: Q, C16: O: R, C16: 1: S, C17: O: T, C17: 1: U, C18: O: V, C18: 1: W, C18: 2: X, C18: 3: Y, C20: O: Z, C20: 1: AA, C22: O: BB, C24: O: CC, lignans: DD, Phenolic acids: EE, flavonoids: FF, luteolin: GG, apigenin: HH, biophenols: II, natural biophenols: JJ, aromatic alcohols: KK, hydroxytyrosol: LL, tyrosol: MM, oleuropein: NN, oleuropein derivatives: OO, ligstrosides: PP, oleocanthal: QQ, cloiridoide acids: RR, decarboxymethylelenolic acid: SS, elenolic acid: TT.

ean olive oils from cultivars *Arbequina*, *Arbosana* and *Koroneiki* and found that climate and soil have a great influence on the phenolic compounds of the oils, and they did not stress the influence of variety. Cetinkaya and kulak [3] also revealed that the level of soil limestone and organic matter influence the level of some fatty acids in olive oils from Turkish cultivars.
According to Laincer *et al* [11] The fine composition of an olive oil, in addition to being highly dependent on the cultivar used for its production, is influenced by several other factors such as climate, soil conditions and farming practices.
Also, the works of Essiari *et al* [23] on the influence of the variety and the culture medium on the fatty acid and polyphenol composition of Moroccan varieties have shown the accentuated effect of the variety, and the area of culture. Douzane *et al* [9], have shown that there is a significant effect of variety on the quality of olive oil. Haddam *et al* [22] have estimated that in addition to the cultural conditions, soil-climatic conditions and extraction methods, the varietal profile contributes with 20% to the physico-chemical and organoleptic quality of an olive oil.

4. CONCLUSION

The tocopherol composition of the seven oils studied have a fairly high percentage of alpha tocopherol, the highest rate being found in *Chemlal* oil SBA with 228,12 mg/Kg, *Sigoise* oil Sebra 1 registers the low value which is from 108,77 mg/Kg. The highest gamma tocopherol content is found in *Oleaster* oil Bensekrane with 11,33 mg/Kg. Variations in the fatty acid profiles of olive oils are noted. Oleic acid is the dominant fatty acid in the composition of the oils studied, it has proportions greater than 60%, the highest value being recorded in *Oleaster* oil Bensekrane with 72.80%. Analysis of the polyphenol composition of the olive oil samples by HPLC reveals a similar qualitative composition in individual phenolic compounds, but different from a quantitative point of view, which allowed us to distinguish between the oils; *Chemlal* oil SBA is distinguished from other varieties by the highest polyphenol contents (328,99 mg/Kg), followed by *Chemlal* Zenata with (216.64 mg/Kg). Our results have shown that the cultivar is an important factor influencing the quantitative composition of total polyphenols in olive oil.

The correlation circle of the variables in the plane of the main components PC1 and PC2 reveals that the first group of phenolic compounds total biophenols, natural biophenols, ligstrosides, lignans, oleuropein derivatives, secoiridoides and oleocanthal, with affinities with a soil parameter which is clay and the geographic parameter which is the altitude of olive groves. The second group composed of flavonoids, tocopherols, palmitic acid, palmitoleic acid, heptadecenoic acid, with affinities with the level of organic matter in the soil and their pH, next to this group distinguish phenolic acids and lignoceric acids which have an affinity with the level of limestone in the soil. While aromatic alcohols (hydroxytyrosol and tyrosol), oleic acid (C18: 1), linoleic acid (C18: 2), gadoleic acid (C20: 1) and peroxide value (PV) was not related to soil and altitude factors. However, fatty acids (C18: 0 (stearic acid), C18: 2 (linoleic acid), C14: 0 (myristic acid), C17: 0 (heptadecanoic acid), C20: 0 (arachidic acid), C22: 0 (acid behenic) with acidity, UV absorbance (K_{270}) and the level of oleuropein were negatively correlated with soil parameters and altitude.

From all the results obtained, we can conclude that the seven samples studied showed an interesting quality in terms of phenolic compounds and fatty acids and provided a lot of information on the quality of olive oils from western Algeria. The results also showed that the contents of phenolic compounds and fatty acids are dependent on the variety, the change in geographical origin, the altitude, and the composition of the soil.

Appendix: Results of oil quality analyzes

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

Means ± standard deviation (n = 3)

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