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Olive oil quality characteristics of olive orchards (*Olea europaea* var. *euroupaea* L.) in a semi-arid continental zone: Case of the Beni Mellal-Khenifra region in Morocco

Elhabty, M.[1*], Ait yacine, Z.[1], Hasib, A.[2], Boundi, A.[3] and Alaoui, M.[4]

[1]Environmental Genius Team, Department of Life Sciences, Faculty of Science and Technology, Sultan Moulay Slimane University, Morocco; [2]Agro-Industrial & Environmental Processes Team, Department of chemistry and environment, Faculty of Science and Technology, Sultan Moulay Slimane University, Morocco; [3]Regional Office of Agricultural Development of Tadla, Morocco; [4]Laboratory for Management and Development of Natural Resources, Faculty of Science and Technology, Sultan Moulay Slimane University, Morocco.

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Abstract The physical and chemical analysis of the quality of olive oil trees (*Olea europaea var. euroupaea* L.) in the years of 2017-2019 period at continental environment with semi-arid climate, Beni Mellal-Khenifra land's, located in central Morocco is revealed territorial specifications. Four homogeneous agricultural territorial units were identified. Result showed the plain with great hydraulic irrigation, the pluviometric plain with private irrigation pumping, the piedmont zone (alias "Dir" zone) and the medium mountain zone. These spatial units had showed significant differences in the values of the essential parameters of quality of the olive oil. The percentage free acidity content were 0.96, 1.76, 1.19 and 1.31, peroxide index (with meq/ O2/kg) were 7.38, 6.34, 10.00, 7. 09, the two specific extinctions under ultraviolet radiation at wavelength 232 nm showed 0.94, 1.34, 0.79 and 0.74, respectively. The wavelength at 270 nm showed non significant difference in the values of 0.08, 0.09, 0.15 and 0.08.–It is found that the agricultural territorial unit "the plain of great hydraulic irrigation" presented significantly the best quality of olive oil. It was nearly equal frequence of class of extra virgin oil (50.02 %), and class of virgin oil (49.48 %). The performance of area is explained by the fertility of the soils, the judicious choice of the plant material, the relatively young age of the olive orchards, the suitable levels of technicality of the local olive growers, and also the respect of the good practices of hygiene by the crushing units with improved mode within the studied area.

Keywords: Beni Mellal Khenifra Morocco region's, Olive oil quality, Olive orchard, Physical-chemical, Semi-arid climat

[*] **Corresponding Author:** Elhabty, M.; **Email:** mohamed.elhabty@usms.ma

Introduction

Olive oil is the famous fat-rich food product preferred by the Mediterranean people since the antiquity. It is the one and only oil that can consumed in its raw form and without prior processing, and has demonstrated over time its nutritional and therapeutic benefits (Boskou, 2006) . The quality of olive oil varies depending on several factors namely: the genetic heritage of the variety and the territory of installation of the crop influencing the chemical quality of olive oil as a product of the plant's metabolism (Essiari *et al*., 2014) . The pedo-agro -climatic conditions, in particular, rainfall during the harvest period and temperature affect the quality of olive oil of the same cultivar (Yu *et al*., 2020). Latitude and altitude affect not only the productivity of the olive tree but also the biochemical properties of its oil (Iddir, 2019). Cultural techniques such as irrigation has a noticeable effect on the constituents of the oil (Jihed *et al*., 2016); high inputs of nitrogen and potassium can afflict both the yield and the quality of olive oil (Bouhafa, 2016). On the other hand, harvesting techniques (Bouhafa, 2016) and the right choice of the optimal date of this operation allows having an oil of better quality (Ait Yacine *et al*., 2001).

However, olives is produced under good agronomic conditions influencing by technological factors including post-harvest olive operations, storage, leaf removal, olive washing, crushing, mixing and extraction techniques clearly affect olive oil quality (Rouas *et al*., 2015).

In contrast, compliance with good hygienic practices (GHP) during the processing and packaging having a direct effect on the quality of olive oils produced (Ouaaziz *et al*., 2016). In particular, the type of materials used in the manufacture of containers for storage or packaging of olive oil as well as the duration and temperature of storage having effects on the qualitative characteristics of extra virgin olive oil (Pristouri *et al*., 2010).

In Morocco, the processing sector includes in 2018 a number of 12020 crushing units, which characterized by the dominance of traditional mills to 92% of its park with a total capacity of 270,000 tons / year and 8% of units improved mode with a capacity of 1223,000 tons / year. In addition, about 68 olive canneries with a capacity of 190,000 tons / year. It is also, noted that the artisanal sector suffers from several deficiencies. Knowing that 3% of these units considered compliant with the required quality standards, the rest of the units continue to operate in a conventional manner. Therefore, their efficiency in the processing of olives into oil remains low in terms of quality given the level of acidity is high; it has concerned in the quantitative level a low rate of extraction following important losses in olive oil (M.C.A, 2018).

At the level of the agricultural study area, the olive tree is occupied a total area of about 120,000 ha (11.5% of the national area), of which 67% is irrigated

and 33% is rainfed area. With a production of 190,000 tons/year which averaged of 5 years, and represented 12 to 13% of the national production, 82% of which is processed in the region. The population variety "*Moroccan Picholine*" represented 78% of the varietal profile of olive growing. The regional production of olive oil by 1800 units, including 190 units with improved mode was 36,000 tons/year (R.D.A.B.K, 2018).

The goals of this research were to precise the knowledge of the quality of olive oil produced by the crushing units in improved mode, and to establish a more reliable regional database.

Materials and methods

Choice of the study area and sampling methods

The present study was conducted during the 2017/2018 and 2018/2019 olive growing seasons in the olive growing region of Beni Mellal- Khénifra, known for its diversity of relief. There are three distinct agro-ecosystems in the studied area. The plain, the piedmont (Dir) and the mountain which decomposed into five agricultural territorial units (ATU) closedly to the Moroccan phosphate plateau. The characteristics of these unit's are designated according to R.D.A.B.K (2018) as follows:-

-ATU1: The plain with large hydraulic irrigation has relatively fertile soils and availability of irrigation water resources, equipped with modern irrigation systems. The plant material is efficient and of suitable age. The density of plantation of olive trees varies between 200 to 1300 feet per hectare.

-ATU2: The pluviometric plain with private irrigation pumping has relatively less fertile soils, and olive tree planting densities ranged between 100 and 200 feet/hectare, and the other agricultural characteristics of the area are similar to those of ATU1.

- ATU3: The piedmont zone (alias "Dir" zone) with soils has a hilly character in the slope and a very heterogeneous fertility. The zone has a microclimate with lower temperatures in summer compared to the ATU1 and ATU2 zones. Irrigation water is quite abundant, with predominance of their farms in small and medium hydraulic mode. The plant material is advanced age. Plantation densities are generally showed between 100 and 200 plants/hectare.

- ATU4: The mid-mountain zone has more uneven soils and higher altitudes than the ATU3 zone, the ambient temperature is lower throughout the year. The cultivation of olive trees is generally conducted in rainy conditions. Plantations are frequently irregular and at a density of less than 100 trees per hectare.

- ATU5: The high mountain lands has soils of low fertility, rocky, skeletal, at high altitude and steep slope pertaining to the middleatlas mountain range.

Olive trees are almost non-existent due to their unsuitability which given very low temperatures in autumn-winter.

Our study are focused on the evaluation of the physical and chemical quality of olive oil produced by crushing units in improved mode in the various agricultural territorial units in the region, except ATU5 which is omitted because it did not contain olives for reasons described above. The mapping of these units is shown on the map in Figure 1.

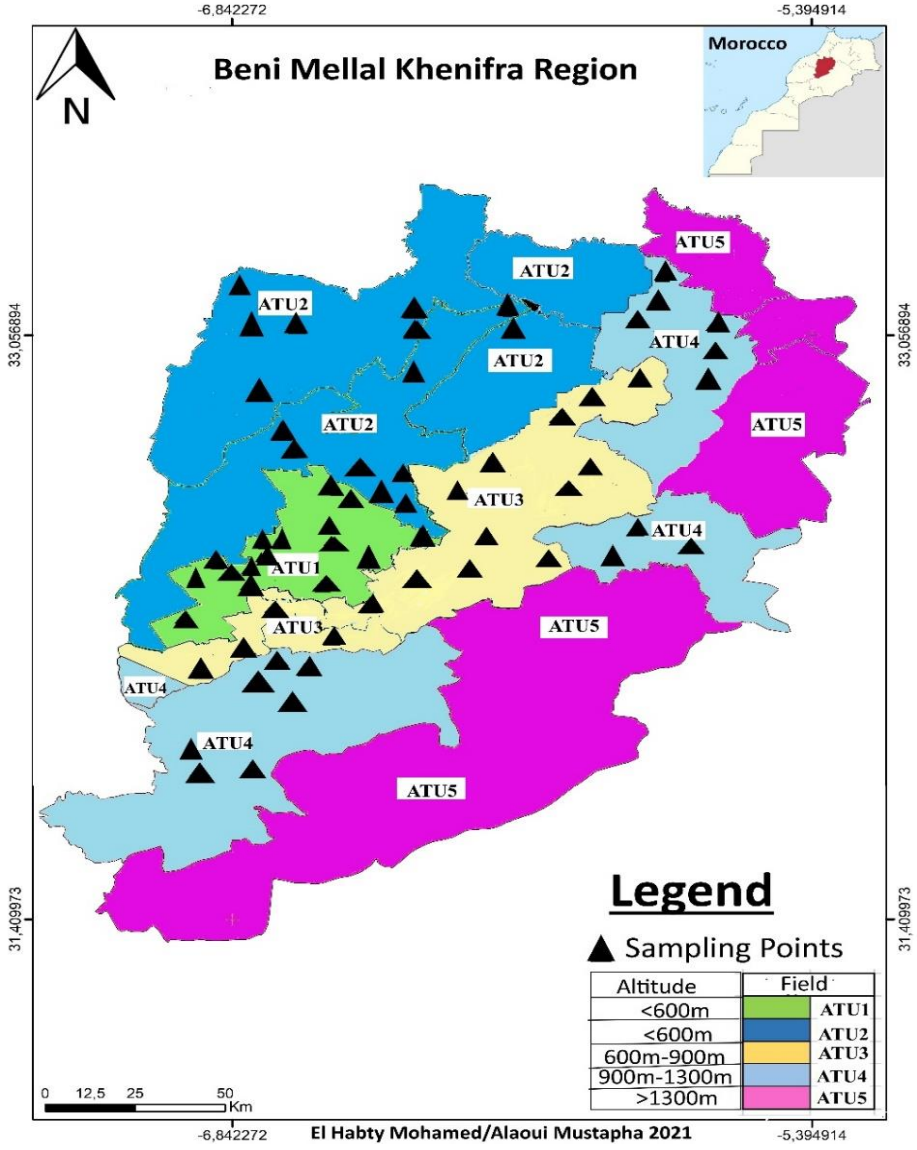


Figure 1. Regional geographic location of the study area and delineation of agricultural territorial unit's (ATU)

Sampling modalities

During the two olive growing seasons 2017/2018 and 2018/2019, a total of 64 olive samples were taken from the trees of farmers residing in the ATU's of the Beni Mellal-Khenifra region at a rate of 16 samples per unit.

Within a period of two days, the collected samples were crushed in the improved mode units which installed in the same ATU's. The crushed olive oils recuperated directly after extraction and stored in smoked glass bottles in the dark to avoid possible oxidation. The harvesting system, transport, storage and preservation were identified for all collected samples.

Methods adoptation

The physical and chemical quality of the olive oils of the ATUs of the region of Beni Mellal-Khenifra were determined according to the commercial standard established by the International Olive Oil Council (IOOC) applicable to olive oils and olive grignion oils. The physical and chemical analysis of olive oil conducted at two laboratories, the Laboratory of Environment and Valorization of Agro-Resources and the Laboratory of Environmental Genius at the Faculty of Science and Technology of Beni Mellal.

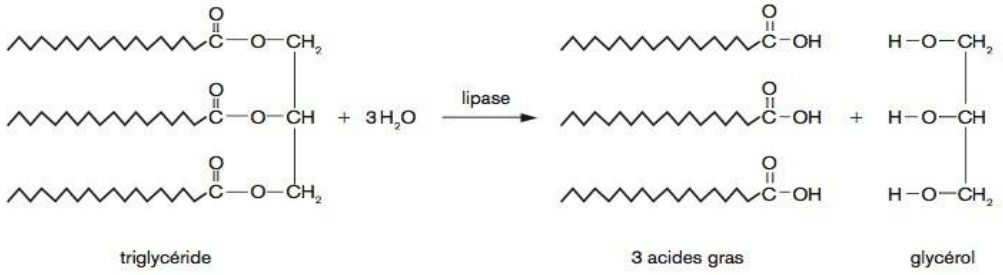
Immediately after the extraction of olives, samples were taken to determine the free acidity of the olive oil samples which allowed the calculation of the percentage of free fatty acids (expressed as oleic acid) presented in the olive oil. The peroxide value (PI) which is expressed in milliequivalents of active oxygen per kilogram of olive oil (C.O.I, 2017) and the specific extinction values is measured by spectrophotometer in the ultraviolet between 232 nm and 270 nm (C.O.I, 2015), it was to determine the oxidation state of the olive oil. Statistical analysis of the data was made by SPSS version 20 software.

Results

Determination of oil quality

Free acidity of olive oil

The measurement of free acidity was detected the alteration of olive oil by hydrolysis under the action of lipases in the pulp of olives. This is manifested by an increase in the content of free fatty acids that oxidize rapidly than those of triglycerides, and during enzymatic rancidity according to the following chemical reaction:



Thus, fruits are damaged by mold attacks, predatory insects and which are subjected to prolonged storage before processing, produced olive oil with higher free acidity. The results of analysis of free acidity of olive oil samples at the level of the four territorial units (ATU) of the region are shown in the Table 1.

Table 1. Results of free acidity analysis (per %) of olive oil samples from the four ATUs

Agricultural territorial unit	**Localization**	**Number of Samples**	**Min**	**Max**	**Medium adidity**	**Ecart type**	**Regional average acidity**
ATU 1	Great Hydraulic Plain	16	0.5100	1.6000	0.9569	0.2809	1.1557
ATU 2	Bour Plain and Private Pumping	16	0.4400	1.8900	1.1700	0.3651	
ATU 3	Piedmont (DIR)	16	0.2800	2.9000	1.1869	0.7826	
ATU 4	Medium Mountain	16	0.4300	2.8000	1.3069	0.7008	
Medium	-	16	0.4150	2.2975	1.1552	0.5324	

Comparing the free acidity of olive oils from different olive growing ATU studied, it noted a significant variability. Indeed, the free acidity of the oil of the area varied from 0.28 to 2.90 with an overall average of 1.16 (Table 1). It is noted that the acidity average of the territorial unit ATU1 was shown below the overall average of the region of 17%, while the unit Plaine Bour and Private Pumping ATU2 and the unit Dir ATU3 were slightly increased by 1% and 3%, respectively which compared to the regional average. This geographical disparity is explained by compliance with good hygiene practices during processing, the immediate crushing of fresh olives upon arrival at the crushing units and by the daily extraction capacity of these units related to the sub-areas.

Indeed, the four agricultural territorial units of the region Beni Mellal-Khenifra is composed at the same time on the same parameter of free acidity,

the results corresponding to these units are compiled in the form of "box to whiskers" in the graph of Figure 2.

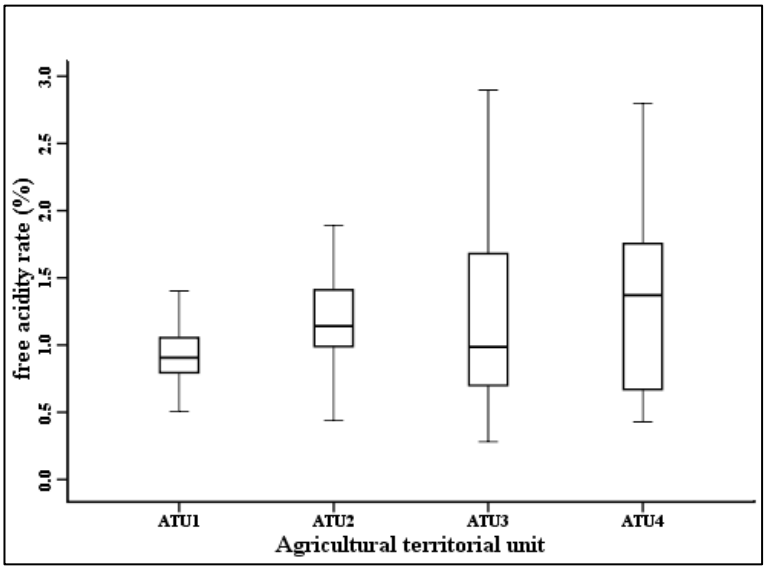


Figure 2. Comparison of the four territorial units according to the free acidity of olive oil spread over the 2017-2019 observation period

According to the above diagram, it noted that the lowest value of free acidity of olive oil in the region is 0.28. It was obtained at the ATU3 extracted by the modern unit of the GIE (Economic Interest Group) of Dir elksiba. Moreover, the highest value of acidity of olive oil in the region was about 2.9 the latter obtained at the ATU3 at the level of a semi-modern unit in the region of Bezou, said overlapping area between the foothills (Dir) and the middle mountain. As for the unit ATU1 (irrigated plain) which is the most homogeneous and is shown overall the best results with the best quality of olive oil according to the parameter free acidity of olive oil. The results of ATU4 are clearly demonstrated to those of ATU1, ATU2 and ATU3. It is implicitly classified the quality of the olive oil of each agricultural territorial unit belonging to the region according to the free acidity is reported in Table 2.

Table 2. Classification of olive oils of the territorial units according to the free acidity of olive oil

Type of the olive oil	Agricultural territorial unit			
	ATU1	ATU2	ATU3	ATU4
"Extra Virgin" olive oil	68.75%	31.25%	49.97%	43.75%
"Virgin" olive oil	31.25%	68.75%	50.03%	43.75%
"Current" olive oil	0.00%	0.00%	0.00%	12.50%

It emerged that 69% of the olive oils of ATU1 and ATU2 were "extra-virgin" and "virgin" respectively, while 50% of the olive oils of ATU3 were virgin against 44% in ATU4. It is possible to deduce the heterogeneity of the quality of olive oils which is produced by the units with improved mode intra and inter territorial agricultural units. Moreover, the classification of olive oil quality by agricultural territorial unit of the study region according to the free acidity of the olive oil was feasible which is illustrated in Figure 3.

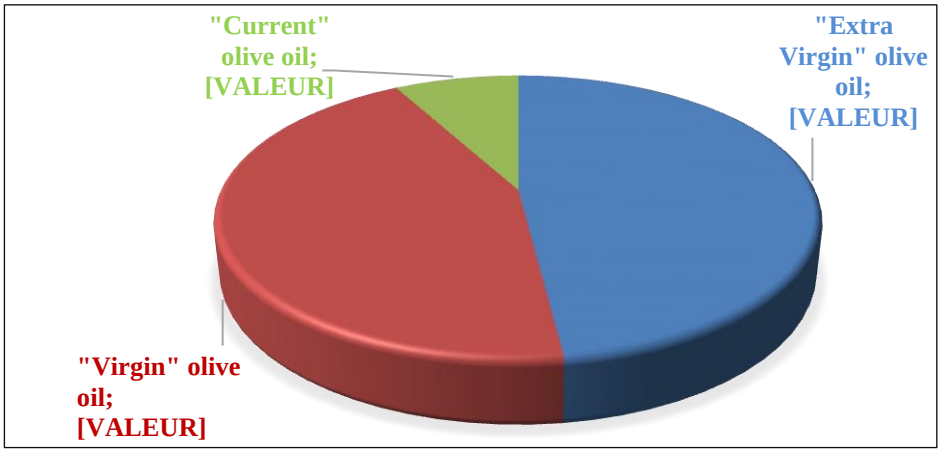


Figure 3. Classification of olive oil according to free acidity measured during the 2017-2019 observation period in the study area

It is appropriately pointed out that despite the positive performance of the modern and semi-modern (improved mode) crushing units of the region. They produced only 48% of extra virgin oils, a proportion of which remained low. Indeed, modern equipment did not improve the quality of olive oil at the best to preserve it as in the fruit at the beginning of the crushing process.

Peroxide index

In addition to free acidity, the quality of olive oil depended on the values of the peroxide index was recorded. The results of analysis of the peroxide value of olive oil from the ATUs of the area are shown in Table 3.

The peroxide indices obtained oscillate between the values of 3.00 and 19.00 meq of O2/kg of olive oil. However, statistical analysis by variance test showed that there was a significant difference between the peroxide indices of olive oils of the different ATUs of the Beni Mellal-Khenifra region (Figure 4).

Table 3. Analysis of the Peroxide Index (by meq of O2/kg in oil) of olive oil of the four ATUs

Agricultural territorial unit	Localization	Number of Samples	Min	Max	Medium adidity	Ecart type	Regional average of the Peroxide Index (IP)
ATU 1	Great Hydraulic Plain	16	3.0000	13.0000	7.3750	3.2223	
ATU 2	Bour Plain and Private Pumping	16	4.0000	9.0000	6.3437	1.2209	7.7031
ATU 3	Piedmont (DIR)	16	3.0000	19.0000	10.000	4.6332	
ATU 4	Medium Mountain	16	3.5000	15.0000	7.0938	3.3676	
Medium	-	16	3.3750	14.0000	7.7031	3.1110	7.7031

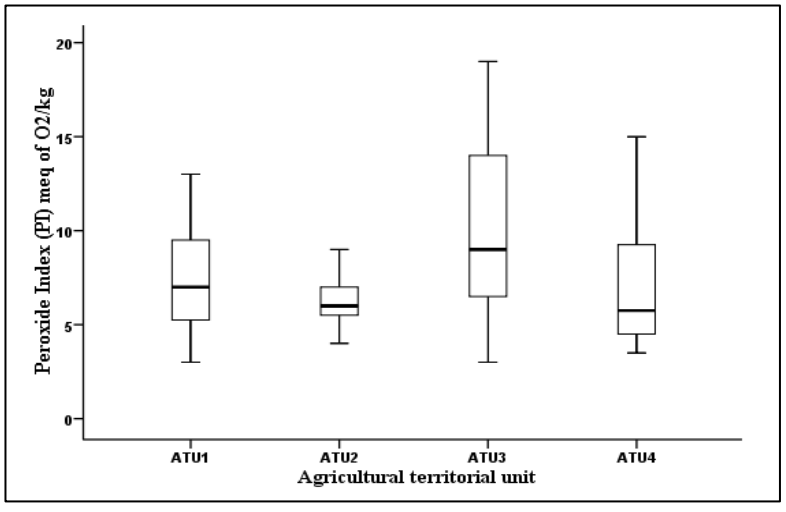


Figure 4. Olive oil peroxide indices of different ATUs during the 2017-2019 observation period of the study area

The highest values of this index are recorded in ATU4 (15 meq of O2/kg) and ATU3 (19 meq of O2/kg) having the average between 7 and 10 meq of O2/kg. These high values of the peroxide index are explained by non-compliance with good hygiene practices, the extraction temperature, the damage of the olives during the harvest and their settling in the storage place, the existence of impurities in the oil, the application of the crushing operations

in the open air and the prolonged contact of the oil with the margines. However, all the oils analyzed peroxide values had much lower than the commercial standard recommended by the COI, which was set at 20 milliequivalents of active oxygen per kilogram of olive oil.

Correlation test between free acidity and peroxide value

The linear correlation coefficient R gave a measure of the intensity and direction of the linear relationship between free acidity and peroxide value of olive oil in the Beni Mellal-Khenifra area (Figure 5).

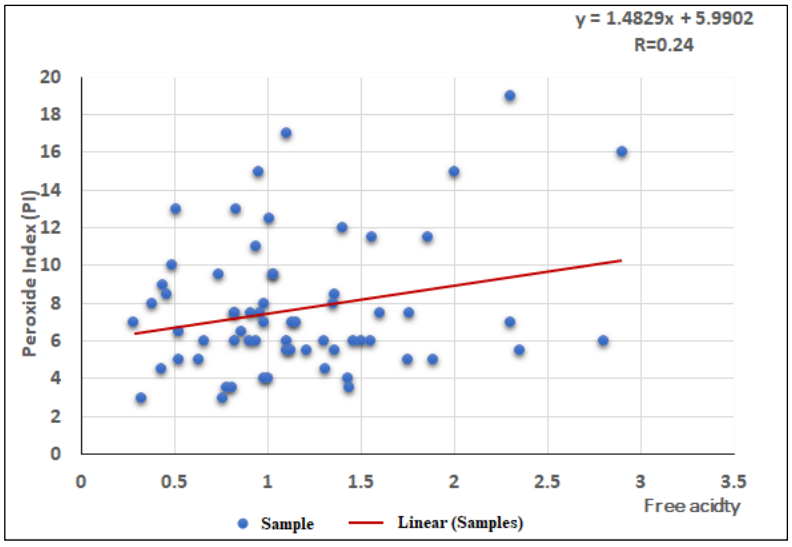


Figure 5. Correlation diagram between free acidity and peroxide value of olive oil of ATUs by linear equation

It showed that the peroxide value of olive oil correlated relatively with the free acidity of olive oil, whose scatterplot of values is shown in Figure 5.

Specific absorbance to ultra-violet rays for olive oil

The oxidation of an olive oil leaded to the formation of linoleic hydro-peroxides and conjugated dienes which absorbed in the vicinity 232 nm. The results of specific extinctions concerning the absorbance to ultra-violet rays of olive oil are determined from spectral photometric readings on products at different sites in the study area are presented in Table 4.

Table 4. Specific absorbance of olive oils in region at Ultra-Violet rays (232 nm and 270 nm)

Absorbance level	**NL1= 232 nm**				**NL 2 = 270 nm**			
Agricultural Territorial Unit	ATU1	ATU2	ATU3	ATU4	ATU1	ATU2	ATU3	ATU4
Total samples	16	16	16	16	16	16	16	16
Minimum	0.2082	0.6329	0.4563	0.2278	0.0272	0.0152	0.0363	0.0260
Maximum	2.1624	2.1309	0.9924	1.3864	0.1509	0.1968	0.2416	0.1139
Medium	0.9409	1.3431	0.7895	0.7348	0.0803	0.0915	0.1524	0.0745
Ecart type	0.5687	0.5184	0.1746	0.3457	0.0408	0.0620	0.0632	0.0321
Variance	0.3230	0.2690	0.0300	0.1200	0.0020	0.0040	0.0040	0.0010

The determination of these absorbances was carried out by a spectrophotometer (Type: Varian Cary 50 Con). The spectrophotometer is connected to a PC on which the results are displayed by means of a software (Figure 6).

Figure 6. Varian Cary 50 Con spectrophotometric measuring equipment linked to the PC (Photos A and B)

Absorbance in the ultraviolet at 232 nm

The absorbance in ultraviolet rays at the wavelength 232 nm oscillates between 0.2082 and 2.1624 nm is showed in Table 4. The comparison of absorbance between olive oils originating from different areas (ATU) of the region showed that almost all the samples of the studied olive oil had an absorbance at 232 nm lower than 2.5 which was the standard set by the COI for extra virgin oils (Figure 7).

It should be noted that following the statistical analysis of these data by the test of equality of means that regionally. There were two distinct groups specific to this absorbance to UV rays (232 nm) which are identified and related to the spatial boundaries. On the one hand for the space ATU2 and on the other hand for the two spaces assembled ATU3 and ATU4, while the space ATU1

confered a situation of intermediary between the two aforementioned geographical groupings (Figure 7 and Figure 1).

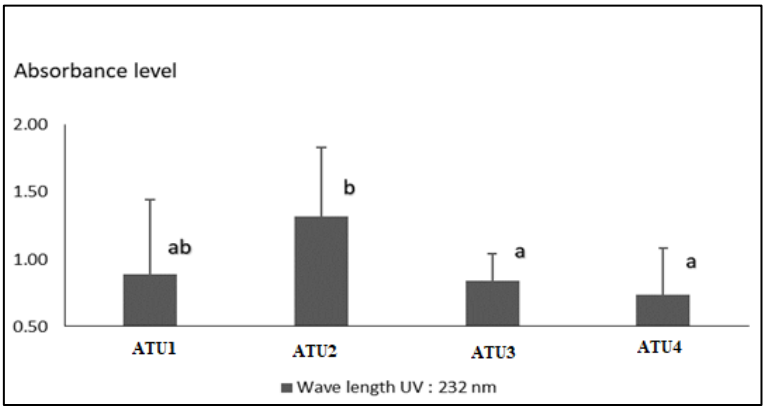


Figure 7. Ultra-violet specific extinctions at 232 nm for the different geographical areas studied during the 2017-2019 observation period

Absorbance in the ultra-violet rays at 270 nm

For UV rays at wavelength of 270 nm, it was found that the average absorbance of olive oil fluctuates in the range of 0.07 to 0.13 depending on the studied geographical area is shown in Figure 8. The results were acceptable and that did not exceed the threshold of the standards recommended by the IOC (E270 nm > 0.22 nm) (C.O.I, 2015).

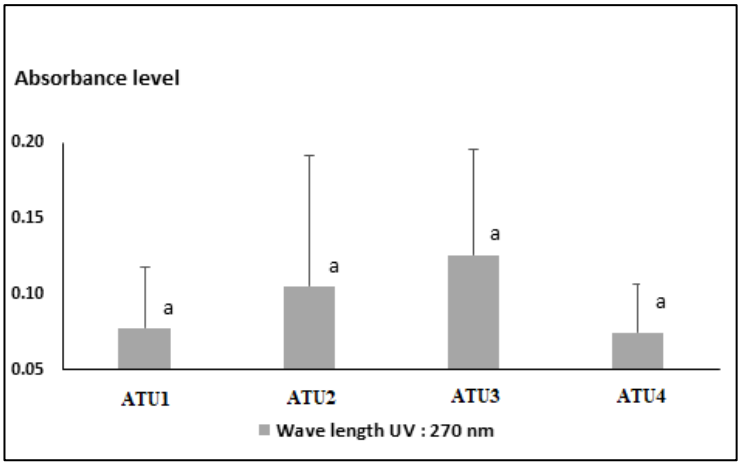


Figure 8. Ultraviolet specific extinctions at 270 nm for the different ATU geographic spaces studied during the 2017-2019 observation period

The statistical analysis of these data through the test of equality of means showed that on the regional level about absorbance to UV rays (270 nm) (Figure 8). It did not identify any significant difference between the different heterogeneous geographical delimitations mapped in Figure 1. Therefore, the specification of olive oil at the regional level remained homogeneous in the entire studied area relied on this technique of absorbance to UV.

Variation in the specific extinction of olive oil

The variation of the specific extinction is indicated by the index (ΔK) allowed to verify, if the oil in question is undergone the refining operation. Indeed, the values recorded for the variation of the specific extinction ΔK showed that the sample n°13 of the ATU1 (Great Hydraulic Plain) and the samples n°04, n°07 and n°08 of the ATU3 (Dir) exceeded the standard of 0.01 set by the COI (year 2015). It is due to the fact that these oils could probably be mixed by remains of other refined or adulterated oils a consequence of the lack of compliance with good hygiene practices in these units. On the other hand, all other oil samples from the different ATU's in the region have ΔK values below 0.01, which were limited foreseen by the standard in force (C.O.I, 2015).

Classification of the quality of the oils of agricultural territorial unit (ATUs) of the Beni Mellal - Khenifra region

The reference classes of olive oil in the study area, according to the standards recommended by the International Olive Oil Council (C.O.I, 2015) are shown in Table 5.

Table 5. Classification of olive oil quality of the territorial units of the study area

Type of the olive oil	ATU1	ATU2	ATU3	ATU4
"Extra Virgin" olive oil	50,02%	37,50%	31,25%	25,00%
"Virgin" olive oil	49,98%	62,50%	43,75%	62,50%
"Current" olive oil	0,00%	0,00%	25,00%	12,50%

The results showed that all the ATU's of the region are dominated by virgin oil, followed by extra-virgin oil. The quality of the olive oil of the Beni Mellal- Khénifra region (Morocco) is described in Figure 9.

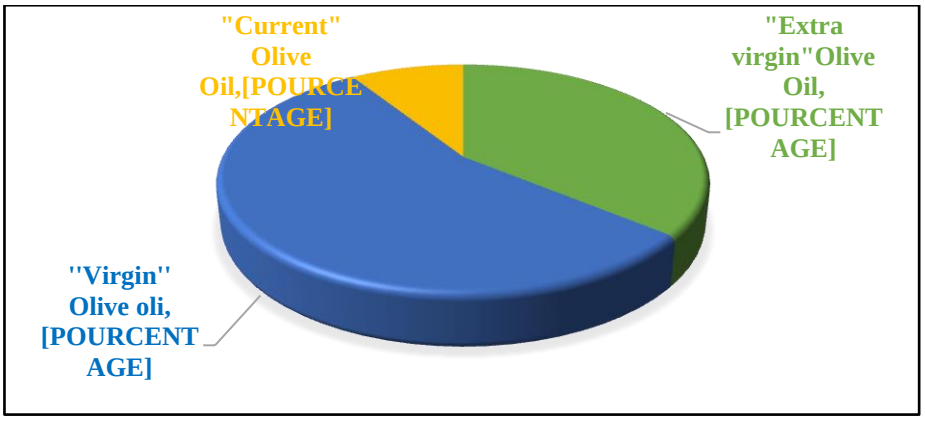


Figure 9. Classification of olive oil in the region over the 2017-2019 observation period by COI standards in 2017 (COI, 2017)

Discussion

The study area is characterized by the dominance of the quality of olive oil type "virgin" (44 to 63%) followed by the extra virgin oil (25 to 50%) and lastly the current category (less than 25%). It is noted that the quality of oils produced in the study area exceeds that of oils at the level of the Chaouia region (Boulfane et *al.*, 2015) and contacted by other rearearch works about the level of this oil in the regions of Marrakech-Tensifet-el Haouz and also Meknes-Tafilalet (Elbir *et al*., 2014). On the contrary, it remains in the vicinity of that recorded in the majority of the rest of the Moroccan territory, especially in relation to the region of proximity Tadla-Azilal (Meftah *et al.*, 2014) and at the level of the mountainous area of Amezmiz for acceptable levels concerning the virgin and extra virgin qualities (Ouaaziz *et al*., 2016). Same observation at the level of eastern Morocco with results of olive oil quality are also between the virgin and extra virgin category (Mansouri *et al.*, 2015).

From the territorial point of view of the study area, it was found that the agricultural territorial unit (ATU1) presented the most satisfactory results of physical and chemical quality, with 50.02% of the samples belonging to the extra virgin category and 49.98% belonging to the virgin category. Furthermore, the agricultural territorial units (ATU3) and (ATU4) contained successively 25% and 12.50% of the "Current" olive oil. These results are consistent with many studies that have shown that the quality of an oil can greatly influenced by its manufacturing process.

The obtained results are contributed to develop a database of characterization and evaluation of physical-chemical characteristics of oils of

the "*Moroccan picholine"* variety grown in agro-climatic conditions (ATU) of the semi-arid region of Beni Mellal-Khenifra. Thus, it contributed to a better knowledge of the quality of olive oil of the said region. It observed that there was some discrimination between the three groups of oil from the four agricultural units of the Beni Mellal-Khenifra region, Plaine Grande Hydraulique, Plaine Bour and private pumping, Dir and the Middle Mountain. The classification of studied oils is shown that all oils subjected to our study crushed in units with improved mode of the region were suitable for consumption, ranging from extra virgin to the current oil. Significant efforts are required in terms of compliance with good manufacturing practices and hygiene to further reduce the share of common oils in the region. Ultimately, these results remained valid for any research in the kingdom a reference guide in the physical-chemical quality to compare other species according to climates and regions in altitude and latitude. The work would be of great scientific and technical interest for future research in this field.

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