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Effects of Cultivar, Maturity Index and Growing Region on Fatty Acid Composition of Olive Oils

Songul KESEN[1*], Asghar AMANPOUR[2], A. Salih SONMEZDAG[3]
Hasim KELEBEK[4], Serkan SELLİ[2]

[1*] The University of Gaziantep, Vocational High School of Naci Topcuoglu, Department of Food Processing, 27310 Gaziantep/Turkey
[2] The University of Cukurova, Faculty of Agriculture, Department of Food Engineering, 01330 Adana/Turkey
[3] The University of Gaziantep, Faculty of Fine Arts, Department of Gastronomy and Culinary Arts, 27310 Gaziantep/Turkey
[4] The University of Adana Science and Technology, Faculty of Engineering and Natural Sciences, Department of Food Engineering, Adana/Turkey

*Corresponding Author: songulkesen27@hotmail.com

Abstract

Olive oil is an important food for people the countries surrounding the Mediterranean Sea and the presence of biologically important minor constituents such as high content of healthy monounsaturated fatty acid (FA). Virgin olive oil (VOO) is valued for its organoleptic and nutritional characteristics, and is resistant to oxidation due to presence of high monounsaturated fatty acid (MUFAs) and low polyunsaturated fatty acid (PUFAs) content. The fatty acid composition of olive oils is influenced by many factors including, climate conditions, geographic area, cultivar, fruit ripeness and agricultural practices. The health benefits of extra virgin olive oil (EVOO) consumption have been related to its well-balanced FA composition. Major FAs in olive oils are oleic (55–85%), palmitic (7.5–20%), linoleic (7.5–20%), stearic (0.5–5%), palmitoleic (0.3–3.5%), and linolenic (0.0–1.5%) acids, and traces of myristic, arachidic, and margaric acids have also been found. Oleic acid is one of the most important FAs in olive oils due to having the nutritional wealth and support for oxidative stability. In consequence, the olive oils differ in composition of fatty acid mainly depending on variety, maturity index and growing region. Therefore, this review may contribute good information about the effect of these principal factors on the fatty acid composition of olive oils.

Keywords: Cultivar, Fatty acid, Growing region, Maturity index, Olive oil

INTRODUCTION

The olive oil production has extended in recent years beyond the Mediterranean basin to non-traditional regions in the southern hemisphere. Turkey is one of the most important virgin olive oil producing countries in the world, coming after Spain, Italy, Greece, Tunisia, Morocco and Syrian Arab Republic.

According to olive oil quantity data released in FAO (2014). Spain (1.738,600 tonnes), Italy (294,914 tonnes), Greece (208,900 tonnes), Tunisia (179,700 tonnes), Morocco (137,400 tonnes), Syrian Arab Republic (100,638) and Turkey (73,915 tonnes) are the most leading countries, respectively.

Among oils, virgin olive oil, a unique crop owing to its elevated nutritional value and sensory properties, is formed by mechanical tools directly from olive fruits in crude form without any other refining processes with regard to further vegetable oils. The olive oils obtained from different cultivars which are from different environments and have different maturity index could differ in quality properties (Rondanini et al., 2014; Borges et al., 2017). In addition to cultivar, geographic area and maturity index many other factors, such as climatic conditions (rainfall, temperature, humidity), agricultural practices and isolation techniques, may also influence the composition and quality of olive oils (Rondanini et al., 2011; Borges et al., 2017).

Olive oil is a fundamental food ingredient recognized for its nutritional qualities and potential health benefits owed not only to its high oleic acid and antioxidant contents but also to its uniquely high level of squalene, which is known to have an anticancer activity (Waterman & Lockwood, 2007), as well as oleocanthal, a secoiridoid phenolic compound with potential therapeutic properties against inflammation, cancer, and neurodegenerative diseases (Parkinson & Russell, 2014). It is well established that the organoleptic properties of olive oil, which are strongly correlated to its geographical and varietal origins, are behind its wide commercialization and elevated market value (Borges et al., 2017).

Virgin olive oil (VOO) is valued for its organoleptic and nutritional characteristics, and is resistant to oxidation due to presence of high monounsaturated fatty acid content (MUFAs) and low polyunsaturated fatty acid content (PUFAs) (Rigane et al., 2012).

The health benefits of olive oil can be related with its chemical composition which has effect on olive oil oxidative stability and quality such as fatty acid composition of olive oil includes palmitic (C16:0), palmitoleic (C16:1), stearic (C18:0), oleic (C18:1), linoleic (C18:2), and linolenic (C18:3) acids. The proportions of fatty acids found in olive oil are the most important factors affecting the nutrition value and quality of the olive oil. While the oleic and linoleic acids are the main fatty acids in the olive oils, linolenic acid is found in small amounts. Oleic acid is a monounsaturated fatty acid and its ratio in olive oil varies according to the ecosystem and season (45-85%). Linoleic acid is a polyunsaturated fatty acid and constitutes 9% of the olive oil (Figure 1) (Bendini et al., 2007).

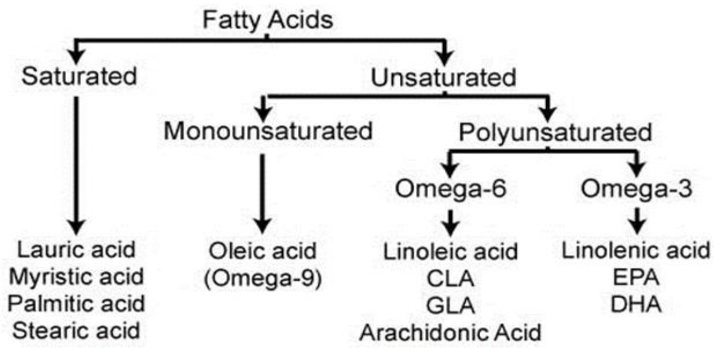

Figure 1. Classification of fatty acids of olive oil

A fatty acid is said to be saturated if each carbon is joined to its neighboring carbons by a single bond. If one or more double bonds is present, the fatty acid is said to be unsaturated. If a fatty acid has only one double bond in the carbon chain, the fatty acid is termed monounsaturated, if a fatty acid has more than one double bond in the carbon chain, the fatty acid is termed polyunsaturated (Figure 2a-2b).

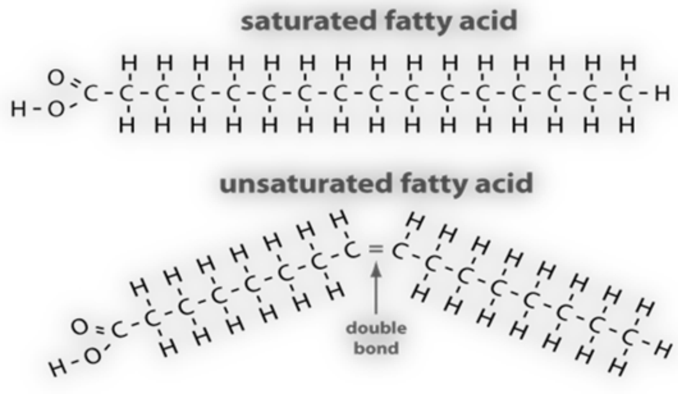

Figure 2a. Types of fatty acids according to presence of double bond

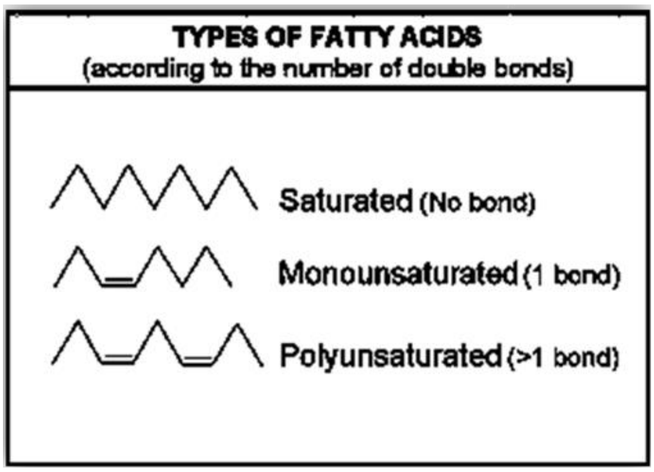

Figure 2b. Types of fatty acids according to number of double bonds

Olive oil extraction using healthy fruits harvested at the right stage of ripening by using proper methods have influence on chemical characteristics of olive oils (Olias et al., 1993). Olive oil is resistant to oxidation because of its low polyunsaturated fatty acid composition and high contents of α-tocopherol and phenolic contents (Sevim et al., 2013).

Among chemical parameters affecting the quality of olive oils, the fatty acid profile is one of the most significant, and this condition may be greatly affected by environmental factors (Borges et al., 2017). The chromatographic analysis of fatty acid methyl esters is applied for the characterization of olive oil and determination of its quality (Zarrouk et al., 2008).

Therefore, due to the importance of fatty acid profile on the oil quality, this review aims to good understand the composition of the fatty acids, and affecting factors (olive variety, maturity index and olive growing region) on these compounds.

Effect of Olive Cultivar On Fatty Acid Composition of Olive Oils

The most important factor affecting oil quality is olive variety. Fatty acid composition may alter among olive oil obtained from different olive cultivars. The effect of olive cultivar on fatty acid composition was studied by different researchers. For example, in Picual, Cornicabra, Manzanilla, Arbequina and Local oils from Spain (Pardo et al., 2007), in Gemlik, Ayvalik, and Memecik from Turkey (Kelebek et al., 2015), in Throumbolia and Koroneiki from Greece (Vekiari et al., 2010) and Mari from Iran (Amanpour et al., 2016). It is known exactly that the main monounsaturated fatty acid in olive oil is oleic acid. High amount of oleic acid in olive oil is of great significance owing to promoting the nutritional wealth by reducing the breast cancer hazard and diminishing the low density lipoprotein (LDL) cholesterol and triglycerides which decline blood pressure and cardiovascular illness as well as enhancing the oxidative stability (Benito et al., 2010). Therefore, as a consequence the high tolerance to oxidation in olive oil is especially because of the high amount of oleic acid.

Ilyasoglu and Ozcelik (2011) determined oleic acid as the most dominant fatty acid in olive oil obtained from Ayvalık and Memecik varieties and quantified as 71.08% and 75.17% for Ayvalık and Memecik variety, respectively.

Douzane et al. (2012) studied fatty acid composition of olive oils obtained from 6 different olive varieties grown in Algeria, they emphasized that varietal difference was an effective criterion on oleic acid and linoleic acid.

Pardo et al. (2007), evaluated the fatty acid composition of virgin olive oils obtained from different olive cultivars in the Campo de Montiel area. The oils of the studied area stood out for their high contents of oleic and stearic acids, and for their low contents of linoleic and palmitic acids. Means and standard deviations for the significant fatty acids composition (%) in the olive oil samples were shown in Table 1.

Table 1. Significant fatty acid composition of virgin olive oils obtained from different olive cultivars in the Campo de Montiel area

Fatty acids	Variety				
	Picual	**Cornicabra**	**Manzanilla**	**Arbequina**	**Local**
Oleic acid (C18:1)	80.7 ± 1.21^{a}	80.0 ± 0.74^{a}	73.5 ± 3.30^{c}	70.6 ± 0.78^{d}	77 ± 0.92^{b}
Palmitic acid (C16:0)	10.5 ± 0.66^{c}	10 ± 0.89^{c}	13.2 ± 0.90^{b}	14.9 ± 0.50^{a}	10.0 ± 1.13^{c}
Linoleic acid (C18:2)	3.51 ± 0.85^{c}	4.09 ± 0.61^{c}	8.34 ± 1.77^{ab}	9.05 ± 0.35^{a}	7.60 ± 0.00^{b}
Stearic acid (C18:0)	2.93 ± 0.29^{a}	3.32 ± 0.43^{a}	2.30 ± 0.34^{b}	$1.70\ 0.00^{c}$	1.95 ± 0.00^{a}

In our previous study (Kelebek et al., 2015), Ayvalik, Gemlik, and Memecik olive varieties cultivated in their respective growing areas were evaluated and compared due to differences in the fatty acids. Thirteen fatty acids were identified and quantified in all samples. Oleic acid was the highest concentration and this acid was more dominant in Gemlik oils. There were significant differences in the mean values of FA composition of the olive oils in relation to varieties. Oleic acid was highest concentration in all oil samples followed by palmitic and linoleic acids. According to the results, the highest amount of oleic acid was found in GEM oil (75.85%) and the lowest in AYV oil (68.95%). However, the amount of palmitic acid was found to be the highest in AYV oil (14.51%) and the lowest in GEM oil (11.42%) (Table 2).

Table 2. Significant fatty acid composition of virgin olive oils obtained from different olive cultivars in Turkey

Fatty acids	Cultivars		
	Ayvalık	Gemlik	Memecik
Palmitic acid (C16:0)	14.51±0.34[a]	11.42±0.96[b]	12.31±1.08[b]
Stearic acid (C18:0)	2.39±0.02[b]	3.35±0.08[a]	2.12±0.08[c]
Oleic acid (C18:1)	68.95±0.42[b]	75.85±0.89[a]	69.57±1.07[b]
Linoleic acid (C18:2)	11.40±0.05[b]	6.49±0.04[c]	13.14±0.10[a]

Ruiz-Dominguez et al. (2013) examined the effects of varietal differences in fatty acids obtained from different olive varieties grown in Valencia, Spain, on fatty acid composition. In the study 45 different olive varieties were used. According to the findings obtained, the varietal difference was statistically significant ($p \leq 0.05$) on all other fatty acids except palmitoleic and margoleic acids. It was found that the predominant fatty acid was oleic acid in all varieties and the amount varied between 56.8-84.2%. The amount of palmitic acid in the second importance was in the range of 7.37-20.38%.

Effect of Maturıty Index on Fatty Acid Composition of Olive Oils

The second factor that is effective on oil quality is the maturity index. Fatty acid composition of olive oils may vary depending on the maturity stage of the olive fruits. The maturity indexes are calculated according to International Olive Oil Council method (IOOC, 2011). Maturity index color scale is used for this purpose. 100 olive samples were randomly selected and classified according to their skin color. This scale has 0-7 colors (Figure 3a) and classification is shown in Figure 3b. The number of olives in each group is multiplied by coefficient and the calculated values are summed and divided by 100. The value found is the maturation index.

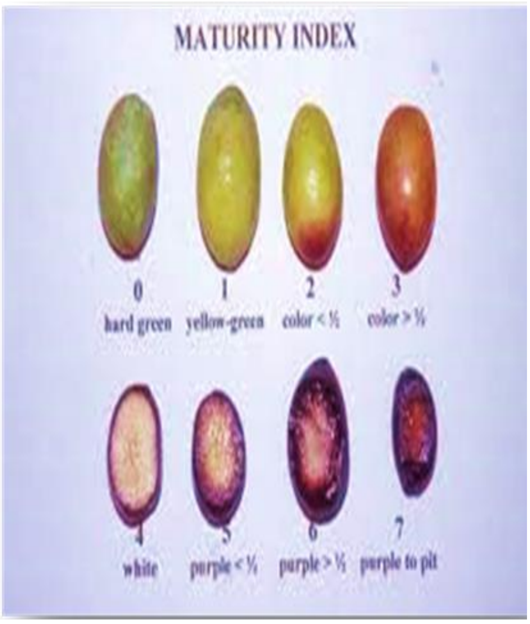

Figure 3a. Coefficients of maturity scale index

Figure 3b. Classification of olives

There are a lot of studies that have shown the formation of fatty acids and their relationship with each other and also effect of maturity index on fatty acid composition.

Ninni (1999) studied of the biosynthetic route of the fatty acids in Greek virgin olive oil during the ripening period of the olive. They pointed out that oleic acid is formed first in the fruit and there is a strong antagonistic relationship between oleic and palmitic, palmitoleic and linoleic acids.

Though the palmitic acid level may remain permanent during the maturation, the ratio of palmitic acid decreases, and the level of oleic acid enhances for the sake of active triacylglycerol biosynthesis. The level of linoleic acid may raise over the maturation because of the production of oleic acid and the activation of enzyme oleate desaturase, which converts oleic acid into linoleic acid. But, in another study fatty acids, such as palmitoleic, stearic and linolenic, remain relatively constant over the normal harvesting stage (Ayton, 2006).

Morello et al. (2004) studied effect of harvesting periods on fatty acid composition. Oils collected from the first week of November to the second week of January were classified as the first harvesting period, and oils collected from the second week of January onwards were classified as the last harvesting period. There was an increase in the percentage of oleic acid as a consequence of the maintenance of the percentage of the saturated fatty acids and decrease of the polyunsaturated ones, linoleic and linolenic acids (Table 3). The unsaturated fatty acids are very important for the stability of oils because of the chemical reactions occurring at the double bonds. The rates of those oxidation reactions depend on the number of double bonds in the carbon chain.

Table 3. Significant fatty acid composition of virgin olive oils obtained from different harvesting period

Harvesting Period	Fatty Acids				
	Palmitic	**Stearic**	**Oleic**	**Linoleic**	**Linolenic**
First harvesting period	13.4	2.39	70.1	10.9	0.76
Last harvesting period	12.3	2.23	74.0	9.1	0.55

Changes in fatty acids were investigated on two different types of Greek olives (Throumbolia and Koroneiki) depending on harvest time. In the study, it was reported that the predominant fatty acid was oleic acid and this acid was changed between 61.07-62.92% in Throumbolia and 74.97-76.33% in Koroneiki variety. In both types, the highest amount was detected in the third maturation phase (black crust color) (Vekiari et al., 2010).

Effect of Growing Region on Fatty Acid Composition of Olive Oils

Fatty acids in olive oil vary depending on the region where the olive tree is located. Due to previous study a significant effect ($P < 0.05$) of the geographic area was observed in the fatty acid profile. The oils from different locations presented the diverse content in MUFA and the PUFA and, consequently, varying MUFA/PUFA ratio (Reboredo-Rodriguez et al., 2015). According to studies of Arbequina olive oils recently produced in Australia, Argentina and Tunisia, different cultivation and environmental conditions may have a strong effect on the fatty acid composition of oils, with oleic and palmitic acids being especially affected (Mailer et al., 2010). Among the environmental factors considered, temperature plays an essential role in the fatty acid composition of oils, by regulating fatty acid desaturases (Hernandez et al., 2011).

It has been shown that low temperatures increase the polyunsaturated fatty acid content of plants, thus maintaining the fluidity of biological membranes. Corroborating this relationship, in the present study a significant association ($P < 0.05$) was recorded between minimum temperatures and the C18:2 and C18:3 content of the oils analysed, whereas maximum temperatures were mainly correlated with the percentages of saturated fatty acids. In Arbequina oils from Argentina, it has been observed that the oleic acid content is dependent on the mean temperature during fruit growth, and can decrease by up to 2% for each ^{o}C of increased temperature (Rondanini et al., 2011).

According to results of some other studies, while Spanish, Italian and Greek olive oils contain a high level of oleic acid and low level of linoleic and palmitic acids, Tunisian olive oils involve a lower level of oleic acid and high level of linoleic and palmitic acids. Based on the data released from different countries, olive oils are categorized in two diverse classes, one is composed of a high oleic acid extent and low linoleic-palmitic acids, and the further entailed a lower oleic acid extent and high linoleic-palmitic acids. Therefore, the low oleic acid content found in those oils, compared with the Spanish, has been attributed to high temperatures (Torres et al., 2009).

Ceci and Carelli (2007) examined the growing region effect on the composition of fatty acids in the oils. For this purpose olive cultivars were obtained from different locations of Argentina. In the study, fatty acids varied according to the region where the olives were cultivated. Borges et al. (2017) analyzed fatty acid profile of Arbequina virgin olive oils produced in different regions of Brazil. The major fatty acid found was oleic acid (C18:1), followed by palmitic acid (C16:0) and linoleic acid (C18:2) (Table 4). A significant effect ($P < 0.05$) of the geographic area was observed in the fatty acid profile. The results obtained provide useful data on the characteristics of Arbequina olive oils from Brazil show that the geographic area of cultivation may affect the physicochemical properties and composition of olive oils. The fatty acid composition of oils was strongly related to environmental factors, particularly with altitude. Thus, findings of the present study reveal that geographic and climate aspects of producing areas may significantly influence the fatty acid composition of Arbequina olive oil.

Table 4. Significant fatty acid composition of Arbequina virgin olive oils obtained from different regions of Brazil

Fatty acids	**Regions**				
	Granada	**Jaén**	**Málaga**	**Cádiz**	**Sevilla**
Stearic acid (C16:0)	11.99 ± 0.10	17.43 ± 0.05	14.14 ± 0.03	16.98 ± 0.68	17.34 ± 0.18
Oleic acid (C18:1)	75.22 ± 0.20	64.09 ± 1.36	71.66 ± 0.07	63.12 ± 0.72	63.85 ± 0.09
Linoleic acid (C18:2)	8.04 ± 0.02	13.17 ± 1.19	9.51 ± 0.00	14.76 ± 0.01	13.77 ± 0.13

Salvador et al. (2003) described the influence of the production area on the fatty acid composition of Cornicabra virgin olive oil. Major fatty acids presented significant statistical differences ($P \leqslant 0.001$) with respect to the production area (five production areas of Toledo and Ciudad Real). The results appear to confirm the general consensus on the quality of Cornicabra virgin olive oils from Castilla-La Mancha, namely that oils from mills located in the south and southeast of the province of Toledo are generally of higher quality (Table 5).

Table 5. Major fatty acid of Cornicabra virgin olive oils obtained from different production areas

Fatty acids	Production Areas				
	Toledo (TO)			Ciudad Real (CR)	
	N	SE 1	SE 2	N	S
Palmitic acid (C16:0)	9.33[b, c]	8.61[a]	8.85[a, b]	9.13[b, c]	9.34[c]
Stearic acid (C18:0)	3.29[a]	3.60[c]	3.47[a,b,c]	3.35[b]	3.56[b, c]
Oleic acid (C18:1)	80.0[a]	80.8[b]	80.7[b]	80.6[a, b]	80.1[a]
Linoleic acid (C18:2)	4.81[b]	4.63[b]	4.49[a, b]	4.36[a]	4.50[a, b]

Piravi-Vanak et al. (2012) studied that the effect of geographical difference of olive cultivation. They reported that fatty acids of oils obtained from twenty seven Iranian olives grown in northern and southern Iran varied according to the olive-growing regions. The samples were collected from different geographical locations that varied in altitude, temperature, humidity and rain fall. According to results oleic acid content of oils in the northern regions was high, but linoleic and stearic acid contents were low than those of southern regions.

CONCLUSIONS

In this review, the effects of several factors including olive cultivar, maturity index and growing region were tried to reveal based on the different studies on fatty acid compositions of olive oils. These works showed that olive oils consist of diverse fatty acids entailing myristic, palmitic, palmitoleic, margaric, margoleic, stearic, oleic, linoleic, arachidic, linolenic, gadoleic and behenic acids. Among them, oleic acid was the most prevailing fatty acid. According to many previous studies on fatty acids of olive oils, it can be said that the composition of fatty acids varies depending on the variety, maturation index and region where the olive grows.

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REFERENCES

Amanpour A., Kelebek H., Kesen S. & S. Selli, 2016. Characterization of Aroma-Active Compounds in Iranian cv. Mari Olive Oil by Aroma Extract Dilution Analysis and GC–MS-Olfactometry, *Journal of American Oil Chemist Society*, 93, 1595–1603.

Ayton J. G. 2006. *The Effect of Harvest Timing and Irrigation on the Quality of Olive Oil*. MSc. Thesis, University of Western Sydney, Australia.

Bendini A., Cerretani L., Carrasco-Pancorbo A., Gomez-Caravaca A. M., Segura-Carretero A., Fernández-Gutiérrez A. & Lercker G. 2007. Phenolic Molecules in Virgin Olive Oils: A Survey of Their Sensory Properties, Health Effects, Antioxidant Activity and Analytical Methods. An Overview of the Last Decade, *Molecules*, 12, 1679–1719.

Benito M., Oria R. & Sánchez-Gimeno, A. C. 2010. Characterization of the Olive Oil from Three Potentially Interesting Varieties from Aragon (Spain), *Food Science Technology International*, 16, 523–530.

Borges T. H., Pereira J. A., Cabrera-Vique C., Lara L., Oliveira A. F. & Seiquer I. 2017. Characterization of Arbequina Virgin Olive Oils Produced in Different Regions of Brazil and Spain: Physicochemical Properties, Oxidative Stability and Fatty Acid Profile, *Food Chemistry*, 215, 454–462.

Ceci L. N. & Carelli A. A. 2007. Characterization of Monovarietal Argentinian Olive Oils From New Productive Zones, *Journal of American Oil Chemist Society*, 84, 1125-1136.

Douzane M., Nouani A., Dako E. & Bellal M. 2012. Influence of the Variety, the Crop Year and the Growing on the Fatty Acid and Tocopherols Composition of Some Algerian Virgin Olive Oils, *African Journal of Agricultural Research*, 7, 4738-4750.

FAO. 2014. Agricultural statistical database. http://www.faostat.fao.org (accessed 24 October 2017).

Hernández M. L., Padilla M. N., Sicardo M. D., Mancha M. & Martínez-Rivas J. M. 2011. Effect of Different Environmental Stresses on the Expression of Oleate Desaturase Genes and Fatty Acid Composition in Olive Fruit, *Phytochemistry*, 72, 178–187.

Ilyasoglu H. & Ozcelik B. 2011. Determination and Seasonal Changes in Olive Oil by Using Differential Scanning Calorimetry Heating Thermograms, *Journal of American Oil Chemist Society*, 88, 907-913.

IOOC. 2011. International Olive Council, Guide for the Determination of the Characteristics of Oil-Olives, COI/OH/Doc. No 1, November (http://www.internationaloliveoil.org). (accessed 24 October 2017).

Kelebek H., Kesen S. & Selli S. 2015. Comparative Study of Bioactive Constituents in Turkish Olive Oils by LC-ESI/MS/MS, *International Journal Food Properties*, 18, 2231–2245.

Mailer R. J., Ayton J. & Graham K. 2010. The İnfluence of Growing Region, Cultivar and Harvest Timing on the Diversity of Australian Olive Oil, *Journal of the American Oil Chemists Society*, 87, 877–884.

Morello J. R., Jose-Motilva M., Tovar M. J. & Romero M. P. 2004. Changes in Commercial Virgin Olive Oil (*cv. Arbequina*) During Storage, with Special Emphasis on the Phenolic Fraction, *Food Chemistry*, 85, 357-364.

Ninni V. 1999. A Statistical Approach to the Biosynthetic Route of the Fatty Acids in Olive Oil: Crosssectional and Time Series Analyses, *Journal of the Science of Food and Agriculture*, 79, 2113-2121.

Olias J. M., Perez A. G., Rios J. J. & Sanz L. C. 1993. Aroma of Virgin Olive Oil: Biogenesis of the Green Odor Notes, *Journal of Agricultural and Food Chemistry*, 41, 2368–2373.

Pardo J. E., Cuesta M. A. & Alvarruiz A. 2007. Evaluation of Potential and Real Quality of Virgin Olive Oil from the Designation of Origin Aceite Campo de Montiel (Ciudad Real, Spain), *Food Chemistry*, 100, 977-984.

Parkinson L. & Russell K. 2014. Oleocanthal, a Phenolic Derived from Virgin Olive Oil: A Review of the Beneficial Effects on İnflammatory Disease, *International Journal of Molecular Sciences*, 15, 12323–12334.

Piravi-Vanak Z., Ghasemi J. B., Ghavami M., Ezzatpanah H. & Zolfonoun E. 2012. The Influence of Growing Region on Fatty Acids and Sterol Composition of Iranian Olive Oils by Unsupervised Clustering Methods, *Journal of the American Oil Chemists Society*, 89, 371-378.

Reboredo-Rodríguez P., González-Barreiro C., Cancho-Grande B., Fregapane G., Salvador M. D. & Simal-Gándara J. 2015. Characterisation of Extra Virgin Olive Oils From Galician Autochthonous Varieties and Their Co-Crushings with Arbequina and Picual cv., *Food Chemistry*, 176, 493–503.

Rigane G., Sayadi S. & Bouaziz M. 2012. *Identification and Antioxidants Activity of Flavonoids from Dhokar and Gemri-Dhokar Olive Cultivars Growing in South of Tunisia. In: Bioactive Compounds*. Editor: A. Bitterlich and S. Fischl. 333-340.

Rondanini D. P., Castro D. N., Searles P. S. & Rousseaux M. C. 2011. Fatty acid profiles of varietal virgin olive oils (Olea europaea L.) from mature orchards in warm arid valleys of Northwestern Argentina (La Rioja), Grasas y aceites, 62, 399–409.

Rondanini D. P., Castro D. N., Searles P. S. & Rousseaux M. C. 2014. Contrasting Patterns of Fatty Acid Composition and Oil Accumulation During Fruit Growth in Several Olive Varieties and Locations in a Non-Mediterranean Region, *European Journal of Agronomy*, 52, 237–246.

Ruiz-Dominguez M. L., Raigon M. D. & Prohens J. 2013. Diversity for Olive Oil Composition in a Collection of Varieties from the Region of Valencia (Spain), *Food Research International*, 54, 1941-1949.

Salvador M. D., Aranda F., Gomez-Alonso S. & Fregapane G. 2003. Influence of Extraction System, Production Year and Area on Cornicabra Virgin Olive Oil: A Study of Five Crop Seasons, *Food Chemistry*, 80, 359-366.

Sevim D., Tuncay O. & Köseoglu O. 2013. The Effect of Olive Leaf Addition on Antioxidant Content and Antioxidant Activity of Memecik Olive Oils at Two Maturity Stages, *Journal of American Oil Chemist Society*, 90, 1359–1369.

Torres M. M., Pierantozzi P., Cáceres M. E. , Labombarda P., Fontanazza G. & Maestri D. M. 2009. Genetic and Chemical Assessment of Arbequina Olive Cultivar Grown in Córdoba Province, Argentina, *Journal of the Science of Food and Agriculture*, 89, 523–530.

Vekiari S. A., Oreopoulou V., Kourkoutas Y., Kamoun N., Msallem M., Psimouli V. & Arapoglou D. 2010. Characterization and Seasonal Variation of the Quality of Virgin Olive Oil of the Throumbolia and Koroneiki Varieties from Southern Greece, *Grasas y Aceites*, 61, 221–231.

Waterman E. & Lockwood B. 2007. Active Components and Clinical Applications of Olive Oil, *Alternative Medicine Review*, 12, 331–342.

Zarrouk W., Haddada F. M., Baccouri B., Oueslati I., Taamalli X. F., Lizzani-Cuvelier L., Daoud D. & Zarrouk M. 2008. Characterization of Virgin Olive Oil from Southern Tunisia, *European Journal of Lipid Science and Technology*, 110, 81-88.