Determination of the Quality and Purity Characteristics of Olive Oils Obtained from Olives Cultivated in Different Regions of Turkey, Depending on Climatic Conditions

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May 9, 2022

Abstract

Virgin olive oils (VOO) obtained from olives grown in different regions of our country, under changing climatic conditions, show different sensory and chemical properties. Due to the fact that primary production is affected by climatic and agricultural conditions and VOOs are supplied to the market by only physical processing. In order to determine whether these deviations are due to climatic conditions, VOOs were obtained from the olive samples collected from 39 orchards in four Region where VOO production is intense in Turkey. Analyzes were carried out regarding the quality and purity criteria of the VOOs. Samples were collected in 2017/18-2020/21 harvest years (-2 on-2 off). The maturity index (MI) values of olives and free fatty acidity (FFA), fatty acid ethyl esters (FAEE), delta-7-stigmastenol values of olive oils ranged between 0.94-4.15 and 0.07-1.27 (in oleic acid %), 1.56-27.32 mg/kg, 0.16-1.14%, respectively. Delta-7-stigmastenol values in 21 samples were outside the limit specified in the legislation (0.50-1.14%). The Fatty acid methyl esters (FAME) and FAEE of all olive oil samples were within the specified limits. In the study, multiple regression analysis was performed to investigate whether there is a relationship between climate data and delta-7-stigmastenol values by years. According to this result, it has been determined that the delta-7-stigmastenol value is high when the annual average relative humidity is low and the annual average temperature is high. There is an urgent need to make forward-looking plans due to climate change.

INTRODUCTION

The olive tree (Olea europaea L) is largely grown in Mediterranean countries and is one of the most important crops grown in this region. In Turkey, olive cultivation is carried out in five regions, namely Aegean, Marmara, Mediterranean, Southeastern Anatolia and Black Sea Regions. Olive varieties in Turkey are distributed as 48.71% Gemlik, 20.66% Ayvalık, 19.11% Memecik, 7.56% Domat and 3.73% other varieties. (Özaltaş et al., 2016). As of 2021, there are a total of 100 registered cultivars, 2 of which are hybrids and 1 of which are clones.

It is known that one of the most important factors affecting the spread of the olive tree is temperature. Generally, it is desired that the annual average temperature is between 15-20°C in olive growing regions. When the maximum temperature rises to 40°C and/or when the minimum temperature is lower than -7°C, olive trees may be damaged. One of the important factors in olive cultivation is precipitation. Although the olive tree is said to be drought resistant, the annual precipitation demand is 600-800 mm. In order for the olive fruit to be larger and of higher quality, water is needed for the development of the kernel hardening in the summer months. Other precipitation types, namely hail and snow, are undesirable precipitation for olive cultivation (Ozturk et al., 2021; Özaltaş et al., 2016). According to the World Meteorological Organization, the hottest days were recorded in 2010-2020. Unfortunately, these changes in climate cannot be stopped and the temperature is expected to increase by 3.4°C by 2095. More extreme weather-related events are expected to increase, accompanied by greater climatic variability and adverse weather events (Maurya et al., 2022). Unfortunately, the increase in drought conditions in Southern Europe in recent years (especially the extreme changes observed in temperature and precipitation in spring and summer) has had negative consequences for olive yield. Even the most optimistic future scenarios show that there may be a decrease in fruit production in most olive growing areas (Orlandi et al., 2020). North African countries are particularly exposed to Mediterranean and Saharan climate changes and weather variability, these countries, which are highly vulnerable to the effects of climate change, should be seriously addressed with appropriate action plans so that olive growers are not affected by these negative effects of climate change (Ben Zaied & Zouabi, 2016). Future climate forecasts point to significant warming and drought trends, and especially the Mediterranean Basin is considered a "hot spot" in terms of climate change (Fraga et al., 2021). Until 2050, there will be a temperature increase of 0.8–2.3°C and a decrease in precipitation in the Mediterranean (Rodriguez Sousa et al., 2020). Future climate changes are of great importance for the agricultural sector as a whole and the olive tree sector in particular (Fraga et al., 2021). The increase in drought conditions observed in some parts of Italy in summer will pose a significant risk in terms of reduced olive production. Increasing temperatures from year to year in Italy are now a testament to climate change, causing olive groves to move inland from the high-temperature coastal plains. Risks to olive production will also increase significantly as more severe changes in temperature or precipitation occur (Orlandi et al., 2020). Global warming will threaten olive groves so that insect and pest populations will increase, in parallel with climate change, olive harvest time will need to be redefined to achieve a balance between high yield and quality of the final product (Algataa, 2020). The predicted changes in terms of annual temperature increases and precipitation decreases will have an impact on many parameters such as the potential distribution area and phenological cycle of olive cultivation (Rodriguez Sousa et al., 2020).

The quality of olive oil is affected by many factors such as agricultural techniques, seasonal conditions, hygienic conditions of fruits, maturity level, harvest time, transportation method and processing technologies (Fontanazza, 1988). The quality of olive oil in National and International Standards; it is evaluated on the basis of FFA, peroxide value, UV specific absorbance values ($K_{232}$and K_{270}), FAEE and sensory properties. Chemical composition of olive oil consists of triacylglycerol (~99%) and FFAs, mono and diacylglycerols, and lipids (Sevim et al., 2019). The fatty acid composition of olive oil varies according to variety, altitude, climate and maturity level of the fruit (Kayahan & Tekin 2006). For this reason, the limits given in both International and National Standards are quite wide. Olive oil contains higher oleic acid, less linoleic and linolenic acid than other vegetable oils. With this feature, it is more resistant to oxidation than other vegetable oils (Papadimitriou et al., 2006). It has been reported that high temperatures change the fatty acid composition and decrease the oil quality by causing a decrease in oleic acid (Nissim et al., 2020). The most important part of the unsaponifiable matter of olive oil is sterols. The composition and content of sterols, which are the predominant components of the unsaponifiable part of olive oil, vary depending on the agronomic and climatic conditions, the quality of the fruit, the extraction and refining technique applied, and the storage conditions. The main sterols of olive oil are; β-sitosterol, delta-5-avenasterol and campesterol. In addition to these, there are low amounts of stigmasterol, cholesterol, 24-methylene-cholesterol, delta-7-campesterol, delta-5,23-stigmastadienol and delta-7-avenasterol (İlyasoğlu, 2009). High level of stigmasterol is associated with high acidity and low organoleptic olive oil quality (Hmida et al., 2022).

Esters of fatty acids and short-chain alcohols in olive oil have been known for more than 30 years. On April 1, 2011, the EU commission made a regulation 61/2011 and established the limits for FAEE parameters for the evaluation of the quality of virgin olive oil. In this way, it is aimed to detect the mixture of natural extra virgin olive oil and low quality oils such as lampant or some deodorized oils. These esters are an indicator of the presence of lampant oil in virgin olive oil (Mariani & Bellan, 2008). FAEE and sensory data are complementary criteria in the classification of olive oil (Gomez-Coca et al. (2012).

During the development of the olive fruit, there are chemical, physical and physiological changes in the olive fruit, and these changes directly affect the table olive and oil quality of the olives. On olive oil quality; variety characteristics, cultural processes, climatic conditions (precipitation, temperature) affect it significantly. It has been important to investigate the effects of changes in climatic events in recent years on the chemical properties of olive oil, especially on purity criteria. So far, no study has been found on the effect of climatic changes on the quality and purity criteria of olive oils in Turkey. In this research, the effect of climate changes on the quality and purity criteria of olive oil was investigated. For this purpose, olive samples from the Marmara Region, Aegean Region, Mediterranean Region and Southeastern Anatolia Region were collected from 39 orchards in the 2017/18-2020/21 harvest years. Olive oils were obtained at the Directorate of Izmir Olive Research Institute. MI of olive fruits, FFA, K_{232} and K_{270}, sterol composition, FAME and FAEE analysis of obtained olive oils were performed.

MATERIALS AND METHODS

Olive oil samples

In the research, it was aimed to collect olive varieties with high economic value and intensive olive cultivation to represent each region of Turkey. In this context, a total of 39 olive samples, from Gemlik, Ayvalık, Memecik, Kilis Yağlık and Nizip Yağlık olive varieties, were collected in 13 different provinces, 15, 9, 9, 3 and 3, respectively.

FIGURE 1 Provinces where olive samples were collected

Olive oils were obtained from 10 kg olive fruits with the Abencor system (MC2 Ingenieria y Sistemas, Sevilla, Spain). Olive samples were washed after being separated from their leaves and crushed in a crusher. It was subjected to mixing (malaxation) at 25°C for 30 minutes. After malaxation, a centrifuge was used to separate the oil from the olive paste. The obtained olive oils were stored under controlled conditions in amber colored bottles at +4°C until the analyses were done after filtering.

Reagents

Fluka (Buchs, Switzerland), Merck (Darmstadt, Germany) and Sigma-Aldrich (Steinheim, Germany) chemicals were used in the analyses.

Maturity Index (MI)

To determine MI in the research, a calculation based on the evaluation of olive skin and pulp colors using 100 olives randomly taken from a 1 kg sample recommended by the International Olive Council (IOC, 1991) was used.

Determination Quality Parameters

The FFA (in oleic acid %) and UV spectrophotometric indices (K_{232} and K_{270} measurements) were measured according to the methods given by Turkish Food Codex (Anonymous, 2014).

Determination of Methyl Esters of Fatty Acids by Gas Chromatography (FAME)

The analysis of FAME of samples was determined using gas chromatography system (HP 6890, Agilent Technologies, DE, USA) equipped with flame ionization detector (FID) described by International Olive Council Methods (modified)–COI/ T.20/ Doc. No.33 2015 (IOC, 2017). DB 23,30m*0.25 mm*0.250 µm capillary column (AgilentJ&WGC Columns, USA) was used for analyses. The injection volume was 1 µl and the temperature of the detector and injector was 250°C. The temperature of the oven was programmed from 170°C to 210°C in increments of 2°C/min. The analysis was terminated by keeping the temperature at 210°C for 10 minutes.

Determination of Fatty Acids Ethyl Esters (FAEE) by Capillary Column Gas Chromatography

The analysis of FAEE contents was made according to the methods in the Turkish Food Codex (Anonymous, 2014). Analysis was performed using Gas Chromatography (Agilent Technologies 6850, USA) using a 15mx0.32mmIDx0.25µm SPB-5 fused silica capillary column. 1 µL of n-heptane solution with helium was used as carrier gas at an injection volume of 0.5 mL/min. The column temperature was adjusted to 80°C, increased at 20 to 140°C/min, then increased to 5 to 335°C/min and waited for 20 min. The detector temperature was set to 350°C.

Determination of Sterol Composition and Amount by Capillary Column Gas Chromatography

The analysis of sterol composition was made according to the methods in the Turkish Food Codex (Anonymous, 2014). Analysis was performed using Gas Chromatography (Agilent Technologies 6850, USA) equipped with flame ionization detector (FID) using a 30 mx0.25mmx0.25µm Supelco 24034 column. The injection volume was 1 µl and the temperature of the detector was 290°C and injector was 280°C. The temperature of the oven was programmed from 260°C. Hydrojen was used as carrier gas at an injection volume of 0.5 mL/min. The flow rate was 0.7/0.8 mL/min. The split ratio was 1:50. It was silylated using Pyridine and BSTFA+TMCS as the silylation reagent. 5α-cholestan-3β-ol was used as internal standard in the analysis. Results were given in both % and mg/kg.

Evaluation of Sensory Analysis in Extra Virgin Olive Oil

Evaluation of sensory analysis of olive oil samples was made according to the method of the International Olive Council, COI/T.20/Doc.no.15 (IOC, 2018). Each taster in the panel first smelled and then tasted the oil in the tasting glass. Oils have positive properties (fruity, bitter, pungent) and negative properties (heating-muddy residue, moldy-moist, vinous-vinegar, metallic, rancid (obsolete-stale), heated or burnt, straw-woody, coarse, machine oil, black water, brine, whitish, earthy, wormy, cucumber, wet wood). Profile paper was used in the evaluation. Scoring was made on the profile paper with a scale of 10 cm. The results were determined by a computer program for obtaining statistical calculations (median).

Statistical Analysis

In this study, the years were analyzed by taking the years again according to the randomized plots. Significance of the differences among the means of olive oils was determined by ANOVA using the Fisher's least significant difference test at $p<.0001$ significance level. Among the chemometric methods in the classification of olive oils; Principal Component Analysis (PCA) and Hierarchical Classification Analysis (HCA) were applied and the obtained data were evaluated with Minitab statistical data analysis program. For the relationship between climate data and delta-7-stigmastenol values, multiple linear regression analysis was applied. All parameters were analyzed duplicate for each sample.

RESULTS AND DISCUSSION

Olive oil analysis

Increasing evidence of significant climate change in the coming decades necessitates adaptation measures. Forecasts point to significant warming and drought trends. Already changes in olive trees have been reported for the past few decades (Fraga et al., 2021). In this study, 4 harvest year (-2 on-2 off) climate data and the oils obtained from the fruits harvested from the regions were examined. It was investigated whether there were deviations in the quality and purity criteria of olive oils.

Harvest time is very important parameter on the quality of olive oil to be obtained from olives. During the maturation of olives, which takes place in two stages, namely green and greenish/pink/black period, a series of important physical and chemical changes occur for both olive and olive oil production (Franco et al., 2014). Olives for oil extraction are generally harvested during the greenish/pink/black period, while olives to be processed into table olives are harvested at different maturity levels depending on the processing method (Emmanouilidoua et al., 2020). As seen Table 1 the lowest MI values was determined from Kilis (KY) with 0.94 in 2018, and the highest was determined from Bursa (G) with 4.15 in 2018 ($p<.0001$). It was determined that the MI values of the Gemlik variety olives were higher, and the Ayvalık and Memecik olive varieties were lower. Maturation time may vary depending on climatic conditions, irrigation, amount of product and variety characteristics (Beltran et al., 2004; Roshani et al., 2016). In the same garden and sometimes even on the same tree, the maturation and coloration of olives do not occur at the same time. Considering that low temperatures and high precipitation delay fruit growth and ripening (Mafrica et al., 2021), climate is very important for MI and fruit quality.

FFA is often the first parameter discussed to assess the quality of olive oil production. It is well known that FFA is affected by many factors, including fruit quality, harvest time, storage and production conditions (Piscopo et al., 2021). According to the years, the lowest FFA was found in Bursa (G) with 0.07 (in oleic acid %) in 2017, and the highest in Çanakkale (A) with 1.27 (in oleic acid %) in 2019. The FFA values of only 2 samples were exceeded the limit of 0.8 (in oleic acid %) for extra virgin olive oil. For that reason they were categorization as VOO (IOC, 2021) (Table 1). As the harvest time progresses, due to the increase in enzymatic activity in the fruit, especially with the increase of lipolytic enzymes, and also due to the sensitivity of olive fruits to pathogenic infections and mechanical damage with ripening, the FFA value increases (Yousfi et al., 2006). UV spectrophotometric indices (K_{232} and K_{270} values) of olive oils were not found to be statistically significant (Table 1).

The presence of methyl and ethyl esters in olive oil is due to the fermentation that occurs in the olive fruit. Therefore, it is the formation of methyl and ethyl alcohols esterified with FFAs. Methyl and ethyl alcohols are higher in lampant oils. These esters are an indication of the presence of lampant oil in VOO. The FAEE value is both a quality criterion and a purity criterion. The FAEE values of samples were found to be statistically significant. According to the years, the lowest FAEE value was determined in Bursa (G) in 2017 with 1.56 mg/kg, and the highest in Balıkesir (A) in 2018 with 27.32 mg/kg (Table 1). Since the FAEE values of all olive oil samples were not exceed the limit of 35 mg/kg, they were classified as extra virgin olive oil in accordance with the IOC standart (IOC, 2021). It has been determined in some studies that FAEE is 30-90 mg/kg in Spanish oils and 1-11 mg/kg in Italian oils. It is generally stated that it is higher in Spanish oils and lower in Italian oils (Garcia-Oliveira et al., 2021). Depending on the olive quality (such as the maturity level of the olive, whether it is damaged or not, the holding time and conditions after harvesting), methanol and ethanol formed by the developing fermentation process are transformed into FAEEs by trans esterification (Mariani & Bellan, 2008). The FAEE value is also often associated with fermentation processes and sensory defects such as moldy/muddy, musty/moist/earthy sediment and wine/vinegar (Di Serio et al., 2017). Addition of water at the oil extraction stage reduces the presence of ethanol, so low FAEE value may not always be an indicator of high quality. It should also be noted that the presence of FAAE at a certain concentration is not always an indicator of low quality, since ethanol is a by-product of fermentation in fruit during flavor development (Gómez-Coca et al., 2016; Garcia-Oliveira et al., 2021). Storage conditions increase the FAEE values statistically significantly, however, the filtration process does not affect the FAEE values (Köseoğlu et al., 2019). As previously investigated by Piscopo et al. (2016) and Mafrica et al. (2021) the FAEE content not affected from the climate of the growing environment or harvesting time, its linked more to processing conditions. Low temperatures and high precipitation slow down fruit growth and development and delay ripening (Mafrica et al., 2021). Therefore, low temperatures, high precipitation and maturity index are very important parameters for olive oil quality.

As seen at Table 1, total beta-sitosterol values were ranged from 93.79% (2020) to 96.68% (2018), delta-7-stigmastenol values were ranged from 0.16% (2019) to 1.14% (2017), campesterol values were ranged from 1.59% (2020) to 3.75% (2017), stigmasterol values were ranged from 0.26% (2017) to 2.22% (2019) and cholesterol values were ranged from 0.00% (2019 and 2020) to 1.77% (2017). All the results were within the limits of IOC (2021) except for delta-7-stigmastenol. The delta-7-stigmastenol value varied between 0.50 and 1.14% in 21 olive oil samples according to years. The other 18 samples were determined below the value of [?]0.5%. Deviations occurred in 5 samples in 2017, 5 samples in 2018, 2 samples in 2019 and 9 samples in 2020. Results are in accordance with Yorulmaz & Bozdogan Konuskan (2017), İlyasoğlu (2009), Ben Temime et al. (2008), Hannachi et al. (2013), Fernández-Cuesta et al. (2013). Most compounds in the sterol composition of olive oil are affected not only by geographical origin but also by environmental conditions (Ben Temime et al., 2008). In some research, it seen that total β-sitosterol concentration values in olive oil increased in the colder region (Piravi-Vanak et al., 2012).

TABLE 1 MI of olives, FFA (oleic acid %), $K_{232}$and K_{270}, sterol composition (%) and FAEE (mg/kg) values of olive oils by years

As seen Table 2, according to the years, the oleic acid, linoleic acid, linolenic acid values ranged between 63.39% (2018) and 75.79% (2017), ranged between 4.47% (2020) and 15.56% (2018), ranged between 0.43% (2019) and 0.91% (2019), respectively (Table 2). Results are in accordance with researchers of Yorulmaz & Bozdogan Konuskan (2017), Köseoğlu et al. (2016), Aparacio & Luna (2002), Mafrica et al. (2021) and Rodrigues et al. (2021). Both the olive variety and the harvest year have significant effects on the FAME of olive oils. In addition, environmental conditions mainly affect oleic acid and linoleic acid content (Rodrigues et al., 2021). Rodrigues et al. (2021), was definitely confirmed that the fatty acid composition changes depending on the olive variety, and it was stated that the climate had an effect on the changes in the fatty acid composition. İlyasoğlu (2009) stated that the chemical composition of Ayvalık and Memecik olive oils varies according to the harvest season, and these changes may be due to changes in climatic conditions (temperature and precipitation amount). It is stated that the irrigation regime positively affects the % oil content and fatty acid composition of olive oil, and the fruit structure in the irrigated regions is better for table olive production and olive oil extraction. In addition, in recent studies, it has been reported that there are differences in the sensory and chemical characteristics of olive oil obtained from trees that are irrigated and grown depending on precipitation (Solinas, 1990; Aparicio & Luna, 2002; Patumi et al., 2002).

TABLE 2 FAME values of olive oils by years (%)

The chemical composition and sensory properties of extra virgin olive oil are affected by many different variables such as environmental factors, cultivation and farming techniques, genetic factors (variety), degree of maturity of the fruit, harvest-transport and storage systems of olives, production techniques, storage and packaging conditions of the oil (Angerosa et al., 2004; Kalua et al., 2007). High temperatures cause losses in some sensory properties and total phenol content of virgin olive oil (Servili et al., 2002). According to the sensory analysis results of fruitness, bitterness and puncency were found to be statistically significant (Table 3). The lowest fruity was determined in Gaziantep (NY) olive oil with 3.68 in 2020 and the highest in Bursa (G) olive oil with 5.33 in 2017. It has been determined that samples are in the "Medium Fruity" group (3.0< median [?] 6) according to the IOC (2021) (Table 3). The bitterness of olive oils by years were not determined statistically significant. The bitterness ranged between 2.10 and 4.20. The lowest pungency in 2019 was obtained from Hatay (G) olive oil with 2.57, and the highest from Gaziantep (NY) olive oil with 4.53. The samples were in the "Medium Bitter" and "Medium Pungent" group (3.0< median [?] 6) and "Light Bitter" and group "Light Pungent" (median [?] 3) in terms of bitterness and puncency according to the IOC (2021). Origin, variety and fruit maturity have a great influence on sensory characteristics of olive oils (Delgado & Guinard, 2011). Results are in accordince with Büyükgök & Gümüşkesen (2015).

TABLE 3 Sensory analysis values of olive oils by years (intensity)

Climate Data and Delta-7-Stigmastenol Value

In this study, multiple regression analysis (multiple linear regression) was performed on climate data (Table 4) and delta-7-stigmastenol values by years. Unfortunately, multiple regression analysis could not be performed on the climate data of 2017, since the total precipitation values in 2017 were different from other years. Maximum temperatures of 31.9 °C, 32.0 °C and 33.2 °C in 2018, 2019 and 2020 were determined in Gaziantep, Şanlıurfa and Şanlıurfa, respectively. In Mersin, Gaziantep and Şanlıurfa, temperatures above 30 °C were detected in every three years. The maximum temperatures in 2018, 2019 and 2020 were determined in Gaziantep with 43.5 °C, 45.6 °C and 42.6 °C. In 2018, 2019 and 2020, the minimum humidity was determined as 32.2%, 30.8% and 44.0% in Şanlıurfa, Şanlıurfa and Antalya, respectively. The minimum average total precipitation was 0 mm=kg÷m^2 in Balıkesir, Hatay, Kilis and Gaziantep in 2018, Aydın, Kilis, Gaziantep and Şanlıurfa in 2019 and Bursa, Muğla, Antalya, Mersin, Hatay, Kilis, Gaziantep and Şanlıurfa in 2020.

TABLE 4 Monthly climate data (temperature, precipitation and humidity)

First of all, correlation analysis was made between climate data and delta-7-stigmastenol values, then 5 candidate climate data with the highest absolute correlation coefficient were selected and multiple regression analysis was performed (Table 5).

TABLE 5 Climate data by years and delta-7-stigmastenol correlation table

In Figure 2 there is a 3D scatterplot graph of the annual average temperature, annual average relative humidity and delta-7-stigmastenol value according to the varieties 2018 (a), 2019 (b) and 2020 (c).

As it can be seen from Table 1 and Figure 2 (a), in 2018 it is determined that the delta-7-stigmastenol values of Gaziantep (NY) and Bursa and Şanlıurfa (G) olive oils are above the limit value of 0.5%, while Mersin (A) olive oil is at the limit. In 2019, we observed that the delta-7-stigmastenol values of Manisa (G) and Mersin (A) olive oils is above the limit value of 0.5% (Table 1 and Figure 2 (b)). According to the Figure 2 (c) the delta-7-stigmastenol values of Bursa, Antalya, Manisa, Hatay and Şanlıurfa (G), Mersin (A), Muğla and Aydın (M) and Gaziantep (NY) olive oils are above the limit value of 0.5% (Table 1). According to the Figure 2 it is observed that the delta-7-stigmastenol values are high when the annual average relative humiditiesare low and the annual average temperatures are high. Efe et al. (2009) investigated the effects of temperature on the phenological and pomological characteristics of different olive cultivars in Turkey and found that extremely high and low temperatures had negative effects on olive growth, quality and yield. High temperature stress, especially high temperatures exceeding 35 to 40 C, affects olive leaf cell membranes and adversely affects olive plants by reducing the leaf water content. Unfortunately, these high temperatures it stops vegetative growth by reducing the rate of photosynthesis (Ozturk et al., 2021).

FIGURE 2 3D scatterplot graph of annual average temperature, annual average relative humidity and delta-7-stigmastenol values according to varieties in 2018 (a), 2019 (b) and 2020 (c)

Principal Components Analysis (PCA) and Hierarchical Classification Analysis (HCA)

The score graph obtained from the PCA analysis of olive oils obtained from the provinces in 2017 according to the variety is shown in Figure 3 (a). According to the PC1 results, the orchards were divided into two main groups, one group where the Gemlik variety was harvested, and the other group where the Nizip Yağlık and Kilis Yağlık varieties were harvested. According to the results of the PC2, the orchards were divided into two main groups, one group where the Ayvalık variety was harvested, and the other group where the Memecik variety was harvested. The border between the two groups is not as wide as the difference between Gemlik and Kilis Yağlık-Nizip Yağlık varieties. The probable reason for this may be that the Gemlik cultivar samples come from a relatively wider range of geographical regions. In 2017, the cultivars were successfully clustered into subgroups on the basis of cultivars according to the orchard from which they were harvested. The loading graph obtained from the PCA analysis is shown in Figure 3 (b). It is seen that the margoleic acid and palmitoleic acid contents are quite determinant especially in the classification and characterization of the Gemlik variety samples. It is seen that one of the most prominent variables in the characterization of Kilis Yağlık and Nizip Yağlık samples were stearic acid. It is seen that the gadoleic acid variable comes to the fore in the characterization of Ayvalık and Memecik cultivars (Figure 3 (b)).

FIGURE 3 (a) Score graph obtained from PCA analysis of olive oils obtained from regions, (b) PCA loading graph of olive oils obtained from the regions in 2017 according to varieties

According to the PC1 results in 2018 (Figure 4 (a)), the orchards were divided into two main groups one group where the Ayvalık variety was harvested, and the other group where the Memecik variety was harvested. According to the results of the PC2, the orchards were divided into two main groups one group where the Gemlik variety was harvested, and the other group where the Nizip Yağlık–Kilis Yağlık variety was harvested.

Varieties were successfully clustered into subgroups on the basis of variety in 2018 according to the orchards from which they were harvested. It is seen in Figure 4 (b) that margoleic acid, oleic acid and palmitoleic acid contents are quite decisive in the classification and characterization of Gemlik samples. It is seen that one of the most prominent variables in the characterization of Kilis Yağlık and Nizip Yağlık samples is arachidic acid. The linoleic acid variant also comes to the fore in the characterization of the Memecik cultivars.

FIGURE 4 (a) Score graph obtained from PCA analysis of olive oils obtained from regions, (b) PCA loading graph of olive oils obtained from regions in 2018 according to varieties

In 2019, the orchards where the Memecik variety was harvested were divided into a group according to the PC1 results (Figure 5 (a)). According to the results of the PC2, the orchards where the Nizip Yağlık variety was harvested are separated as a group. In 2019, the cultivars were successfully clustered into subgroups only as Memecik and Nizip Yağlık, according to the orchards where they were harvested. When the loading graph was examined closely, it was determined that the linoleic acid, linolenic acid and gadoleic acid contents were quite determinative in the classification and characterization of the Memecik variety samples (Figure 5 (b)). It was determined that one of the most significant variables in the characterization of Nizip Yağlık samples was arachidic acid.

FIGURE 5 (a) Score graph obtained from PCA analysis of olive oils obtained from regions, (b) PCA loading graph of olive oils obtained from regions in 2019 according to varieties

In 2020, the orchards where Kilis Yaglik and Nizip Yaglik varieties were harvested were divided into a group (Figure 6 (a)). According to the results of the PC2, the orchards where the Memecik variety was harvested were separated as a group. In 2020, the cultivars were successfully clustered into subgroups only as Memecik and Kilis Yağlık-Nizip Yağlık according to the orchards where they were harvested. It has been determined that linoleic acid contents may be determinant in the classification and characterization of the Memecik samples (Figure 6 (b)). It is seen that one of the most prominent variables in the characterization of Nizip Yağlık samples is arachidic acid.

FIGURE 6 (a) Score graph obtained from the PCA analysis of olive oils obtained from the regions, (b) PCA loading graph of olive oils obtained from regions in 2020 according to varieties

CONCLUSIONS

Considering that the Mediterranean Basin is considered to be a "hot spot" in climate change, it is stated that this situation may become more challenging especially for olive growers. Increasing evidence of significant climate change that may occur in the coming years necessitates the adoption of adaptation measures, in order to effectively deal with the anticipated changes, both short and long term adaptation strategies have been adopted by industry stakeholders and decision makers to adapt to a hotter and drier future. It is stated that the expected increases in temperatures depending on the changes in the climates may increase the length of the growing season in olives, cause changes in the phenological timings, especially in flowering, and that higher temperatures and increased evaporation will accelerate fruit ripening, revealing the need for early harvest even at lower maturity levels. It is known that olive oils obtained from olives grown in different regions in our country, under changing climatic conditions, show different characteristics from each other. Due to the fact that primary production is affected by climatic and agricultural conditions. This study was carried out to investigate whether these deviations occur due to agricultural or climatic reasons.

According to results of research the MI values of olives varied between 0.94-4.15, FFA 0.07-1.27 values ranged between (in oleic acid %), FAEE values ranged between 1.56-27.32 mg/kg, oleic acid values varied between 67.26-73.77%, linoleic acid values varied between 6.14-12.83%, linolenic acid values varied between 0.52-0.81% and delta-7-stigmastenol values ranged between 0.16-1.14%. International standards specify the delta-7-stigmastenol limit value as [?]0.5%. It was determined that delta-7-stigmastenol values of 21 samples between 0.50-1.14 above this value according to years and provinces (varieties). In our research, multiple linear regression analysis was performed to investigate whether there is a relationship between climate data and delta-7-stigmastenol values by years. First of all, correlation analysis was made between climate data and delta-7-stigmastenol values, then 5 candidate climate data with the highest absolute correlation coefficient were selected and multiple regression analysis was performed. As a result of the multiple regression analysis, it was determined that the delta-7-stigmastenol value was high when the annual average relative humidity was low and the annual average temperature was high.

Future climatic predictions reveal that perennial crops such as olive trees, especially water, physiological processes, phenological timings, can have serious adverse effects on final yield and quality characteristics. There is an urgent need to make forward-looking plans due to climate change. Projects should be made by focusing on how the olive varieties will behave depending on climate change. In the development and selection of new olive varieties; Criteria such as resistant to diseases and pests, resistant to high temperatures and drought, high quality and antioxidant properties of table and oil olives should be taken into consideration.

ACKNOWLEDGMENTS

This project was supported by the Republic of Türkiye Ministry of Agriculture And Forestry General Directorate of Agricultural Research And Policies (TAGEM). In the execution of the project, cooperation was made with the General Directorate of Food and Control, Department of Food Businesses and Codex and the General Directorate of Plant Production.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHOR CONTRIBUTIONS

Didar SEVİM: Methodology, Investigation, Oil Extraction, Analysis, Writing, Editing, Supervision, **Oya KÖSEOĞLU:**Investigation, Oil Extraction, Formal Analysis, **Durmuş ÖZDEMİR:**Statistic, Software, **Mehmet HAKAN:** Field Observation, Sample Collection, Statistic, Software, **Elif B. BÜYÜKGÖK:** Oil Extraction, Formal Analysis, **Hatice USLU:** Data Collecting, Analysis, **Özgür DURSUN** : Field Observation, Sample Collection,**M. Kerem SAVRAN:** Field Observation, Sample Collection,**Önder ERALP:** Field Observation, Sample Collection,**Serkan KAPTAN:** Field Observation, Sample Collection,**Halil KÖKTÜRK** : Field Observation, Sample Collection,**Özlem ASKER:** Oil Extraction, Analysis**, Sibel PAZARLI:**Formal Analysis, **Melike AYAZTEK:** Formal Analysis,**Nurdan AKBAŞ:** Formal Analysis, **Serkan YALÇIN:** Formal Analysis, **Pınar Çakır TOPDEMİR:** Formal Analysis.

ETHICS STATEMENT

This research did not involve any human or animal study and institutional ethical approval was not required.

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ETHICAL APPROVAL

This article does not contain any studies with human participants or animals performed by any of the authors.

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Figure Captions

FIGURE 1 Provinces where olive samples were collected

FIGURE 2 3D scatterplot graph of annual average temperature, annual average relative humidity and delta-7-stigmastenol values according to varieties in 2018 (a), 2019 (b) and 2020 (c)

FIGURE 3 (a) Score graph obtained from PCA analysis of olive oils obtained from regions, (b) PCA loading graph of olive oils obtained from the regions in 2017 according to varieties

FIGURE 4 (a) Score graph obtained from PCA analysis of olive oils obtained from regions, (b) PCA loading graph of olive oils obtained from regions in 2018 according to varieties

FIGURE 5 (a) Score graph obtained from PCA analysis of olive oils obtained from regions, (b) PCA loading graph of olive oils obtained from regions in 2019 according to varieties

FIGURE 6 (a) Score graph obtained from the PCA analysis of olive oils obtained from the regions, (b) PCA loading graph of olive oils obtained from regions in 2020 according to varieties

Table Captions

TABLE 1 MI of olives, FFA (oleic acid %), $K_{232}$and K_{270}, sterol composition (%) and FAEE (mg/kg) values of olive oils by years

TABLE 2 FAME values of olive oils by years (%)

TABLE 3 Sensory analysis values of olive oils by years (intensity)

TABLE 4 Monthly climate data (temperature, precipitation and humidity)

TABLE 5 Climate data by years and delta-7-stigmastenol correlation table

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