SİDAS MEDYA
Akademik Gıda®
ISSN Online: 2148-015X
https://dergipark.org.tr/tr/pub/akademik-gida

Akademik Gıda 20(3) (2022) 220-231, DOI: 10.24323/akademik-gida.1186763

Research Paper / Araştırma Makalesi

Improvement of Olive Oil Quality with Innovative Olive Cleaning System

Didar Sevim[1], Oya Köseoğlu[2], Uğur Şumnulu[3], Pınar Kadiroğlu[4], Mehmet Erdan[3], Mehmet Tosun[3], Aslı Yıldırım Vardin[5]

[1]İzmir Olive Research Institute, Ministry of Agriculture and Forestry, Bornova, İzmir
[2]İzmir Olive Research Institute, Ministry of Agriculture and Forestry, Bornova, İzmir
[3] HAUS Machinery Industry and Trade Company, Efeler, Aydın
[4]Department of Food Engineering, Faculty of Engineering, Adana Alparslan Türkeş Science and Technology University, Sarıçam, Adana
[5]Department of Food Engineering, Faculty of Engineering, Aydın Adnan Menderes University, Efeler, Aydın

Received (Geliş Tarihi): 22.11.2021, Accepted (Kabul Tarihi): 19.09.2022
Corresponding author (Yazışmalardan Sorumlu Yazar): didar.sevim@tarimorman.gov.tr (D. Sevim)
+90 232 462 7073 (137) +90 232 435 7042

ABSTRACT

Turkey is considered the homeland of olives and is one of the important olive oil producers of the world. With the increasing number of trees, the necessity to complete olive harvest in a short time, like 3-4 months, makes mechanization necessary. The use of mechanical devices during olive harvest causes an increase in the number of leaves, shoots, and branches in the harvested product. Leaf separation systems used in cleaning non-olive materials in olives are generally inadequate in cleaning olives containing dense leaves obtained due to the use of new generation harvesting machines. For this reason, to develop an innovative sorting/cleaning prototype to provide more efficient cleaning, it is necessary to determine the machine efficiency, oil efficiency, olive oil quality and composition of machines. Total phenolics, chlorophyll and carotenoid contents, induction period and DPPH antioxidant activity values of olive oil obtained after traditional suction fan system (TSFS) application were higher than olive oils obtained after new generation blown and drum sieve system (NGBDSS) application. However, the α-tocopherol content of olives was low in the samples obtained by TSFS. The fatty acid composition of olive oils obtained from both applications was similar. Our study determined that there were 13 volatile compounds in the olive oil obtained after applying the TSFS, and there were 6 volatile compounds in the olive oil obtained with the application of NGBDSS. When the sensory properties of olive oils were analyzed, it was found that olive oils obtained from both applications were similar to the fruitiness, bitterness, and pungency of olive oils obtained after applying NGBDSS.

Keywords: Extraction system, Olive leaf, Olive cleaning machine, Olive oil quality, Antioxidant

Yenilikçi Zeytin Temizleme Sistemi İle Zeytinyağı Kalitesinin İyileştirilmesi

ÖZ

Ülkemiz, zeytinin anavatanı olarak kabul edilmekte olup, Dünya'nın önemli zeytinyağı üreticilerinden biridir. Zeytin hasadının 3-4 ay gibi kısa zamanda tamamlanma zorunluluğu, artan ağaç sayısı ile birlikte hasatta mekanizasyonu gerekli kılmaktadır. Zeytin hasadında mekanik cihazların kullanımı toplanan üründeki yaprak, filiz ve dal parçalarının miktarının artmasına sebep olmaktadır. Zeytinlerdeki yabancı maddelerin temizlenmesinde kullanılan yaprak ayırma sistemleri genellikle yeni nesil hasat makinelerinin kullanımı sonucu elde edilen ve yoğun yaprak içeren zeytinlerin temizlenmesinde yetersiz kalmaktadır. Bu sebeple daha etkin bir temizleme sağlamak için yenilikçi ayıklama/temizleme prototipi geliştirmek; makinelerin etkinliğini, yağ verimini, zeytinyağı kalite ve kompozisyonunu belirlemek gerekmektedir. Geleneksel emme fanlı sistem (GEFS) uygulaması sonrasında elde edilen zeytinyağının

toplam fenolik, klorofil ve karotenoid miktarları ile indüksiyon periyodu ve DPPH antioksidan aktivite değerlerinin, yeni nesil üflemeli ve tambur elekli sistem (YNÜTES) uygulaması sonrasında elde edilen zeytinyağlarına göre daha yüksek olduğu, bununla birlikte α-tokoferol miktarının ise daha düşük olduğu belirlenmiştir. Her iki uygulamadan elde edilen zeytinyağlarının yağ asidi kompozisyonu değerlerinin benzer olduğu tespit edilmiştir. Uçucu bileşenler açısından çalışmamızda GEFS uygulaması sonrasında elde edilen zeytinyağında 13 adet, YNÜTES uygulaması ile elde edilen zeytinyağında ise 6 adet uçucu bileşen olduğu tespit edilmiştir. Duyusal özellikler bakımından her iki uygulamadan elde edilen zeytinyağlarının meyvemsilik, acılık ve yakıcılık şiddetlerinin benzer olduğu belirlenmiştir.

Anahtar Kelimeler: Ekstraksiyon sistemi, Zeytin yaprağı, Zeytin temizleme makinası, Zeytinyağı kalitesi, Antioksidan

INTRODUCTION

Automatic olive picking machines, which have recently started to be used in Turkey, have become commonplace, especially in Southern Europe, especially in Spain and Italy. As a result, suitable machinery is not produced in Turkey to clean olives that come to the facilities with more leaves and branches. In some regions of Turkey, due to the low oil rate, olives are expected to be lubricated by not picking, but when they fall from the branch to the ground, they are collected with vacuum machines and scoops. Due to this collection process, olives include many foreign materials such as sand and stone. Virgin olive oil is obtained by washing, decantation, centrifugation and filtration processes and mechanical and physical processes in a thermal environment that will not change the natural qualities of the olive tree fruit; It is an oil that carries the physical, chemical, and sensory properties of the products in its category [1]. Changes in olive oil composition are affected by many factors such as variety, ripening, harvest, post-harvest storage, process conditions, and monitoring these changes is of particular importance in terms of consumer health [2]. Many parameters affect the quality of olive oil. These are harvest time and maturity level (30%), extraction methods (30%), variety (20%), storage conditions (10%), harvesting methods (5%) and transportation (5%) [3].

Olives are generally picked up by hand or harvesting machines. Olives that fall to the ground are collected directly or with the help of nets laid under the tree. Depending on the climatic conditions and the olive harvesting method, foreign materials can reach up to 5-15% of the olives harvested (Figure 1). These foreign substances coming from outside should be removed to prevent undesirable effects that may cause on the quality of virgin olive oil and also prevent damage to high-speed rotating equipment such as crushers, decanters, and separators used in the continuous system.

In modern systems (two-phase and three-phase continuous systems), sorting and washing processes are generally applied together during cleaning olives that come to the plant. These machines separate olive grains and foreign materials from each other by using an aspirator and pressurized water. The washing machine is operated together with the conveyor belt. After the olives are placed in the bunker, they are transported with the help of conveyor belts and passed through an absorbent aspirator.

Leaf removal from olives is always recommended, primarily when mechanically harvested. The presence of leaves changes the flavor and aroma of the oil during the extraction stage of the oil. Olive leaves broken with olives cause an increase in the green color of virgin olive oil and the "green" or "leaf" feeling in its sensory properties. Sometimes these features are preferred by consumers, and sometimes they are not. The efficiency of the olive crushing method and the size of the leaves also change these features. Metallic crushers are usually violent crushers, breaking the leaves into many small particles. Thus, the sensory properties, color, aroma, and flavor of extra virgin olive oil can change [4].

Olive oil consists of 98% of glycerides and fatty acids as the major components and 2% of the minor components. The oleic acid content of olive oil is 55-83%, the linoleic acid content is 3.5-21%, and linolenic acid content is below 1% [1] There are 230 minor components such as phenolic compounds, tocopherols, sterols, hydrocarbons, antioxidants in olive oil [5]. The fatty acid composition, phenolic compound content, tocopherol amount, sterol composition, and pigment content of olive oil change with maturation. These changes depend on the variety, climate and growing conditions and affect olive oil quality, sensory properties, oxidative stability, and nutritional value [6].

Oxidative stability and total phenolic contents were analyzed on the oils obtained from Memecik, Erkence, Domat, Nizip Yağlık, Gemlik, and Ayvalık olive varieties [7]. The total phenol was determined 330.92 mgGAE/kg oil, 356.65 mgGAE/kg oil, 301.99 mgGAE/kg oil, 102.40 mgGAE/kg oil, 274.09 mgGAE/kg oil, respectively. Sevim et al. [8] investigated the total phenol, α-tocopherol, chlorophyll, and carotenoid amounts and DPPH antioxidant activity in a study conducted with oils obtained from Ayvalık, Memecik, Gemlik, and Uslu olive varieties, which are important olive varieties of our country. Their study found that the total amount of phenolic substance ranged from 46.15-383.67 mg CAE/kg oil, and the amount of α-tocopherol ranged between 194.99-340.44 mg/kg.

Ilyasoğlu et al. [9] reported that that α-tocopherol and total phenol content of oils obtained from Ayvalık and Memecik cultivars, which are important olive varieties grown in the Aegean Region, ranged between 155.17-325.25 mg/kg and 76.14-226.31 mgCAE/kg oil, respectively.

Malheiro et al. [10] stated in their study that olive leaves, which are by-products of olive oil extraction, constitute 10% of the total olive. Clodoveo et al. [11] stated that many olive oil producers subject olives to a separate cleaning process in order to purify them from leaves and other foreign materials, thus preventing the devices and equipment from being affected by foreign substances and preventing foreign substances and foreign odors that may arise from leaves in the oil.

Figure 1. An example of an olive harvest; olive harvest leaf density

Currently, the suction fans used in olive oil plants are insufficient for separating dense leafy olives; these fans are often clogged and work inefficiently. In addition, almost no cleaning can be done on the olives that come with their branches, and these unwanted branches negatively affect the taste and aroma of olive oil.

This study aims to eliminate the negative factors in olive oil production in Turkey, raising the awareness of producer farmers and facilities and ensuring that quality olive oil is obtained. In this direction, it is necessary to deal with the olive oil production facility from the very beginning. Our study discussed the first processing stage of the olive coming to the facility, the separation of the olive from the branches and leaves. It is also aimed to produce and consume conscious and healthy olive oil with innovative solutions. In addition, feeding the olive to other equipment without removing hard and abrasive foreign materials such as stone, sand, metal causes damage to equipment, extra maintenance/replacement costs, downtime of the plant, and even a loss of prestige for machinery and olive oil producing companies. Another goal of the research is to help olive oil plants and machinery companies avoid material losses and increase customer satisfaction. For these reasons, the study aims to increase the foreign market share of machinery producing companies.

For this purpose, the content of moisture % and oil % in olive paste, the amount of free fatty acid in olive oil (in oleic acid %), the number of peroxides, specific absorption values in ultraviolet light (K_{232}, K_{270}), total phenol amount, total chlorophyll and carotenoid amount, fatty acid composition, amount of α-tocopherol, DPPH antioxidant activity, induction period, volatile compounds analysis and sensory analysis have been performed.

MATERIALS and METHODS

Maturity Index

The olive maturity index (MI) was determined according to the method given by the International Olive Council [11] based on the evaluation of the olive skin and pulp colors.

Olive Analysis

The moisture content (%) of the olive samples was determined according to TSE [13] TS EN ISO 665 and the oil content (%) was determined according to TSE [14] TS EN ISO 659. After weighing 15 grams of olive fruit, it was dried in the oven at 105°C until constant weight and moisture content (%) was calculated. The oil content was measured with Soxhlet extraction. After that percentage of oil was calculated.

Extraction of Olive Oil

In this study, the Memecik cultivar was used. Olive samples were collected by machine harvesting from Belenkuyu Davutlar (Aydın, Turkey) in November 2019. Olive oils were obtained with a 3-phase continuous system. Olives coming to the factory are divided into two, and they are separated from their leaves in two separate lines with the help of both traditional suction fan system and new generation blew system and drum sieve system. With the traditional suction fan system, 11 kg of leaves were extracted from 273 kg of leafy olives (Figures 2), and 24 kg of leaves were extracted from 293 kg of olives with the new generation blown and drum sieve system (Figures 3). Olives, whose leaves were removed, were crushed with a hammer crusher after washing and were subjected to malaxation at 30-35°C for 30-45 minutes. Then, olive oil, pomace, and olive oil mill wastewater were separated from the olive pastes with the help of a vertical separator, and the olive oil obtained was purified from the remaining impurities

by passing through a separator with 200L of water per hour (Figure 4). The obtained olive oils were stored at +4°C for analysis.

a b c

Figure 2. Harvest with relatively few leaves (a); two fan system (b); washing; and the remaining leaves (c)

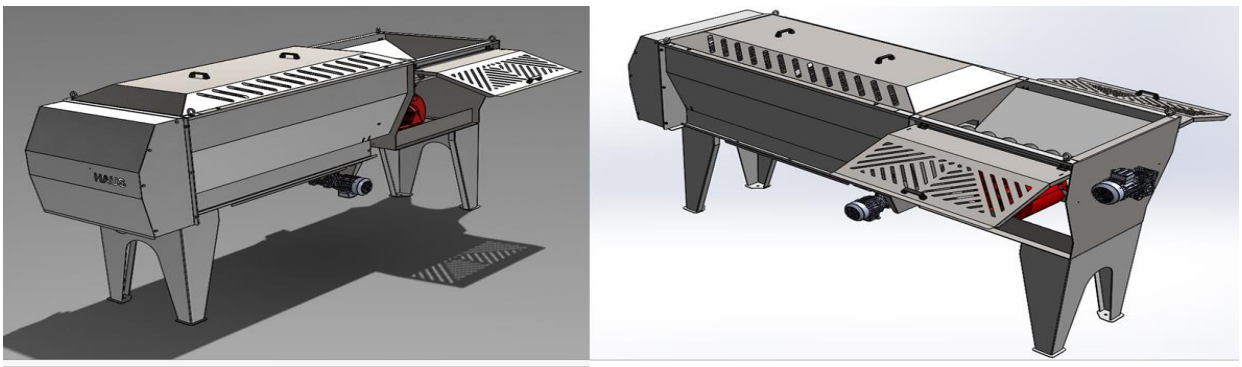

Figure 3. From our project; Two-way view of olive branch leaf sorting machine with double drum blowing fan

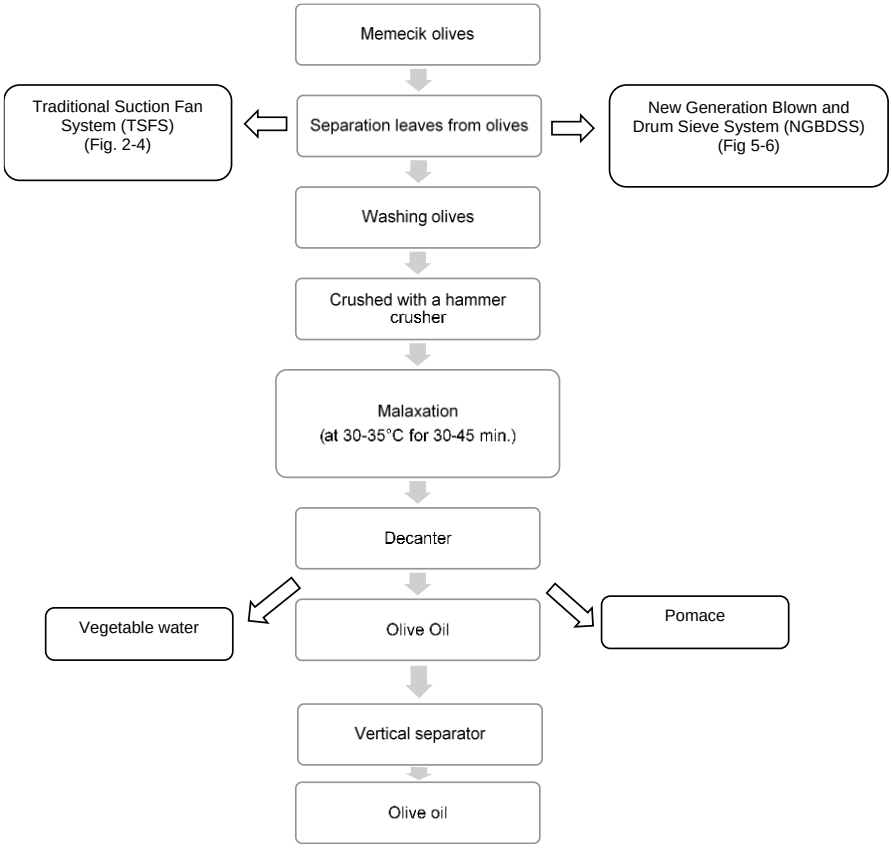

Figure 4. Three phase continuous system with traditional suction fan system (TSFS) and new generation blown and drum sieve system (NGBDSS)

Quality Parameters

The free fatty acidity (FFA), the peroxide values (PV) and UV spectrophotometric indices (K_{232} and K_{270} measurements) were determined according to Turkish Food Codex [14]. All parameters were determined duplicate for each sample.

Fatty Acid Composition

The determination of methyl esters of fatty acids of olive oils by gas chromatography was carried out according to COI/ T.20.Doc.no:33 [16]. Determination of fatty acids in olive oil samples was made using a flame ionization detector (FID) and a DB-23 capillary column (30m x 0.25mm i.d. x 0.250 µm) in HP 6890 model Gas Chromatography device. In the analysis, an oven program with 2°C/min increments between 170°C and 210°C was applied, and the analysis was completed by keeping the samples at 210°C for 10 minutes. A standard mixture containing a mixture of methyl esters of 37 fatty acids (Sigma-Aldrich Chemicals 189-19) was used for the identification of fatty acids. The results were calculated as % area with the help of the HP 3365 Chemstation computer program.

Antioxidant Components and Antioxidant Activity Analysis of Olive Oil

Tocopherol Analysis

Tocopherol analyses (α, β, γ, δ) were determined by using High-Pressure Liquid Chromatography (HPLC 1100 series) according to Carpenter [17], Dabbou et al. [18] and IUPAC [19] methods. The oils were diluted 1/10 with hexane containing 1% isopropyl alcohol, filtered with Econofilter 25/0.45 µm RC (Agilent Technologies) and injected into High-Pressure Liquid Chromatography. The injection volume was 20 µL. µ-porasil column was used 250 mm * 4.6 mm * 5 µm (Waters, Ireland). The flow rate was 1 mL/min. The temperature of the column was set to 25ºC.

Total Phenol Content

Total phenol in olive oils was determined according to the method proposed by Gutfinger [20]. 2.5 g olive oil was dissolved in 5 mL hexane and stirred for 2 minutes with the addition of 5 mL methanol/water (60:40 v/v) for the extraction of phenolic substances. The hexane and methanol/water phases were separated from each other by centrifugation at 3500 rpm for 10 minutes [21]. Total phenol analysis was performed in the methanolic phase. Measurements were made in a spectrophotometer (UV-1700,Shimadzu, Japan) at a wavelength of 725 nm. The results were given as mg CAE/kg oil.

DPPH• Antioxidant Activity

The antioxidant capacity of olive oil samples was determined according to Jiang et al. [22], Carrasco-Pancorbo et al. [23], and Lavelli [24]. It was determined by spectrophotometric measurement of the neutralization process of DPPH• (Aldrich Chemical Co. Milwauke, WI), a strong free radical (2,2-diphenyl-1-picrylhydrazil). 100 µM DPPH• radical was prepared with methanol. After adding 1.9 mL of DPPH• solution to 0.1 mL of extract and keeping it in the dark for 15 minutes, absorbance values were measured at 517 nm wavelength.

Oxidative Stability Analysis

The oxidation stability of oils was carried out according to the Rancimat method with a computer-controlled and fully automatic, oxidation stability measuring device Rancimat 743 (Metrohm Ltd., Herisau, Switzerland) in fats and oils for analytical and research laboratories. It was determined by exposing 3 g of oil to an airflow rate of 20 L/h and a block temperature of 120°C [25].

Total Chlorophyll and Carotenoid Analyses

7.5 g of olive oil sample was dissolved in cyclohexane and completed to 25 mL in a volumetric flask. Carotenoid and chlorophyll content of the sample was determined by measuring the solution at 670 nm and 470 nm with a spectrophotometer (UV-1700, Shimadzu, JAPAN), respectively [26].

Sensory Analysis

A sensory analysis was carried out by the panel, which is recognized by the International Olive Council and has an ISO 17025 accreditation certificate. The sensory profile was conducted by the Turkey Olive Research Institute olive oil panel according to the official methods of IOC-COI/T.20/Doc. No 15/Rev. 10 [27]. Eight panelists (4 woman, 4 man) ranging in age from 33 to 58 years old, were fully trained in the evaluation of virgin olive oil. A tasting glass was filled with 15 mL of each olive oil sample. The samples were kept at a constant temperature of 28± 2° C. Each taster in the panel first smelled and then tasted the oil in the tasting glass. Oils were evaluated according to 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 evaluated by a computer program for obtaining statistical calculations (median).

Volatile Compounds Analysis of Olive Oils

Firstly 3 g of olive oil sample was weighed into 20 mL headspace vials and closed with a leakproof Teflon cap. The samples were incubated at 40°C for 10 minutes and then extraction was carried out for 30 minutes. DVB/CAR/PDMS (Divinlybenzene/ carboxen/ polydimethylsiloxane) (50/30 µm) fiber was used for solid-phase microextraction. The volatile compounds of the samples was then determined by gas chromatography-mass spectrometer (GC-MS)

(Shimadzu, Japan). The separation was performed using a Restek Rxi-5MS capillary column (30m x 0.25mm x 0.25 µm). The carrier gas was helium with a flow rate of 1.5 mL/min. The inlet temperature was 230°C and operated in splitless mode. Ion source and interface temperatures were set at 250°C. The oven temperature program used was as follows: 50°C, isothermal for 2 minutes; increased at 4°C/min to 230°C, isothermal for 10 minutes. Volatile compounds were identified using the GC-MS library (Wiley GC-MS Library, 2010) [28].

Statistical Analysis

Principal component analysis (PCA) was performed using Minitab® 17 program (Minitab Inc., State College, PA, USA) in order to evaluate the classification pattern of the olive oil samples obtained from olives separated from their leaves with NGBDSS and TSFS systems according to olive analysis, quality parameters and fatty acid composition analyses.

RESULT and DISCUSSION

Olive Analysis

The degree of maturity of the olive is a crucial factor in determining the harvest time. Harvest maturity depends on the color of the fruit skin and fruit flesh. The MI calculated by comparison from the color scale is used to determine the maturity.

Oil accumulation in olive fruit begins in late July and early August. With the decrease in temperatures, olive ripening begins and the oil content of the fruit increases day by day. In the period from October to December, the amount of oil increases. During the autumn and winter seasons, the fruit's skin color turns black, and the amount of oil reaches its maximum [29]. The ideal harvest time is when the oil has the maximum quality and best sensory properties. After the maturation is completed, the oil content in the dry matter remains constant, but the water ratio decreases [30]. The ripening period, in which olive oil reaches its maximum, does not usually coincide with the period when the oil has the best quality and sensory properties.

As seen in Table 1 the MI of Memecik olive fruits was determined as 1.95 (Olive fruit olives with yellow or yellowish skin color). The moisture content of the fruits used in the TSFS was determined as 54.24% and the oil content as 23.10%. The moisture content of the fruits used in the NGBDSS was determined as 58.33% and the oil content as 17.73%.

Table 1. Maturity index, moisture content and oil content of olive fruits*

Parameter	TSFS	NGBDSS
Maturity index	1.95±0.00	1.95±0.02
Moisture content (%)	54.24±0.90	58.33±0.53
Oil content (%)	23.10±1.10	17.73±1.66

*: TSFS: Traditional suction fan system, NGBDSS: New generation blown and drum sieve system

Quality Parameters

Olive oil quality criteria are affected by many factors such as climatic conditions, olive fruit quality, maturity, harvesting methods, transportation, olive oil production systems and storage. The higher the quality of the olive fruit we have, the higher the quality of natural extra virgin olive oil, if the extraction is done under appropriate conditions.

It was determined that the FFA, PV, K_{232} and K_{270} values of olive oil samples obtained from the TSFS application were higher than olive oils obtained from the NGBDSS application (Table 2). According to the Turkish Food Codex, olive oil samples obtained from both applications are classified as Virgin Olive Oil in terms of FFA, PV, K_{232} and K_{270} values.

Table 2. Free fatty acidity value (% oleic acid) (FFA), peroxide value (meqO_2/kg oil) (PV), K_{232} and K_{270} values of olive oil samples*

Parameter	TSFS	NGBDSS
FFA	1.83±0.01	1.38±0.00
PV	8.42±0.10	7.51±0.09
K_{232}	1.63±0.06	1.31±0.03
K_{270}	0.16±0.00	0.12±0.01

*: TSFS: Traditional suction fan system, NGBDSS: New generation blown and drum sieve system

The addition of leaves increases the FFA and PV in olive oils obtained by adding olive leaves, K_{232} and K_{270} values slightly increase in oils with 1, 2.5 and 5 leaf additions, and significantly increase in oils with 10% leaf addition. Depending on the high rate of leaf addition, K_{232} and K_{270} values may exceed the determined international legal limits [10]. Sevim [3] stated that the addition of leaves at different rates did not have a fixed effect on the FFA, PV and K_{232} values (sometimes it increased and sometimes did not cause a change based on year and variety), but increased the K_{270} value. Gibriel et al. [31] reported that leaf addition caused a slight increase in FFA and no change in PV. However, Di Giovacchino et al. [32] stated that the addition of leaves at different rates had no effect on the FFA, PV, K_{232} and K_{270} values. Tarchoune et al. [33] determined that the addition of 3% olive leaf did not cause any change in the FFA and PV in the oil obtained from Neb Jmel variety, which is a Tunisian variety, while it caused a decrease in the FFA and PV in the oil obtained from the Oueslati variety.

Fatty Acid Composition

The fatty acid composition of olive oil varies according to the fruit's variety, altitude, climate, and maturity level. It is known that as the temperature decreases and the altitude increases, the level of unsaturated fatty acids also increases. Olive oils obtained from cold regions have been found to have high oleic acid levels and low linoleic acid levels [34, 35]. The study conducted by İlyasoğlu [36] on Memecik and Ayvalık olive cultivars determined that the chemical compositions of olive oils changed according to the olive variety and harvest season. It is stated that the climatic characteristics of the

geographical region where the olives are grown, the temperature and the amount of precipitation are effective on the chemical composition of olive oil, especially on the fatty acids and antioxidant substance content.

Palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, SFA, MUFA and PUFA values of olive oils obtained from TSFS were determined 12.82%, 2.49%, 72.38%, 9.87% 0.72%, 88.25%, 73.42%, and 10.59%, respectively. For NGBDSS application, palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, SFA, MUFA, and PUFA values of olive oils were determined 12.72%, 2.38%, 73.25%, 9.10%, 0.73%, 88.94%, 74.31%, and 9.83%, respectively (Table 3). When the fatty acid composition values of olive oils were examined, it was found that the fatty acid composition values of the olive oils obtained from both applications were similar.

Table 3. Fatty acid composition of olive oil samples (%)*

Fatty acid	TSFS	NGBDSS
Myristic acid (C14:0)	0.02±0.00	0.02±0.00
Palmitic acid (C16:0)	12.82±0.07	12.72±0.03
Palmitoleic acid (C16:1)	0.94±0.08	0.93±0.04
Stearic acid (C18:0)	2.49±0.07	2.38±0.03
Oleic acid (C18:1)	72.38±0.00	73.25±0.00
Linoleic acid (C18:2)	9.87±0.00	9.10±0.01
Linolenic acid (C18:3)	0.72±0.00	0.73±0.00
SFA	88.25±0.04	88.94±0.01
MUFA	73.42±0.07	74.31±0.03
PUFA	10.59±0.00	9.83±0.01

*: TSFS: Traditional suction fan system, NGBDSS: New generation blown and drum sieve system. SFA: Saturated Fatty Acids; MUFA: Monounsaturated Fatty Acids; PUFA: Polyunsaturated Fatty Acids

Dıraman and Dibeklioğlu [37] stated that the oleic acid, linoleic acid and linolenic acid values of Memecik olive oil's varied between 72.06-77.07%, 8.03-10.05% and 0.61-0.68%, respectively. The values we obtained are consistent with the study. Sevim [3] stated that the addition of leaves to olives does not have a fixed effect on the fatty acid composition of the oil obtained. Malheiro et al. [38] stated that the addition of leaves had no effect on the fatty acid composition of olive oil samples obtained in 2009. In 2010, 10% leaf addition caused a decrease in oleic acid content and an increase in linoleic acid content, Gibriel et al. [31] stated that the leaf addition had no effect on the fatty acid composition.

According to the PCA biplot for the fatty acid composition of olive oils, the first two principal components represent 90.4% of the total variability (Figure 5). C14:0 was discarded from the data because myristic acid (C14:0) values did not change among the samples. C18:1, MUFA, SFA, C20:1, and C18:3 were effective in the characterization of olive oils obtained from olives applied with NGBDSS. Olive oil replicates after TSFS application were also separated on the left part of the plot.

Antioxidant Components and Antioxidant Activity Analysis of Olive Oil

Olive leaves are raw materials that do not have any production or purchasing costs, and recent scientific studies have revealed that olive leaf phenolic compound content, especially oleuropein content, is relatively high. After its fruit, the olive leaf, which is the most nutritious part of the olive tree, contains many phenolic compounds and tocopherols that show antioxidant properties. The antioxidant activity of oleuropein and hydroxytyrosol in olive leaf extracts is also very high [3]. Olive leaves are an important by-product obtained during the harvest of olive trees [39].

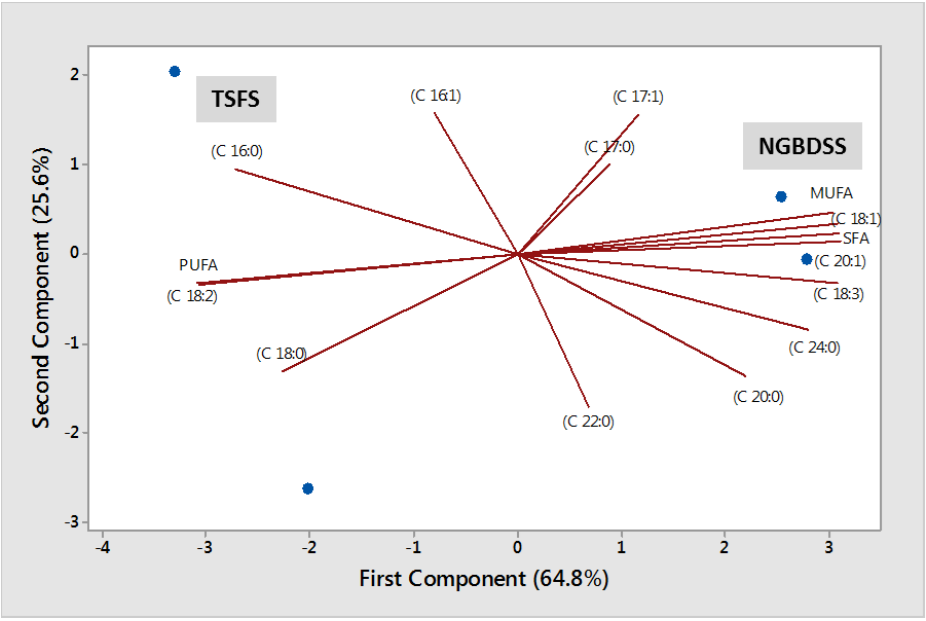

Figure 5. PCA biplot of oil samples according to fatty acid composition (TSFS: Traditional suction fan system, NGBDSS: New generation blown and drum sieve system)

Table 4. Total phenol (mg CAE/kg oil) (TP), α-tocopherol (mg/kg) (AT), β- tocopherol (mg/kg) (BT), γ-tocopherol (mg/kg) (GT), δ- tocopherol (mg/kg) (TT), chlorophyll (mg/kg) (CH) and carotenoid (CA) amounts (mg/kg), oxidative stability (h) (OS) and DPPH antioxidant activity values (µmol TE/kg of oil) (DPPH AAV) of olive oil samples*

Olive Oil	TP	AT	BT	GT	TT	CH	CA	OS	DPPH AAV
TSFS	136.94±3.59	227.35±0.69	8.37±0.43	2.22±0.76	27.57±0.69	8.82±0.03	4.28±0.04	7.96±0.34	41.86±1.02
NGBDSS	65.93±3.59	239.49±0.98	6.71±0.86	3.07±0.24	24.39±1.04	6.87±0.09	3.15±0.03	6.76±0.04	32.99±0.77

*: TSFS: Traditional suction fan system, NGBDSS: New generation blown and drum sieve system

As seen in Table 4, TP, AT, BT, GT, TT, CH, CA, OS and DPPH AA values of the olive oils obtained from the TSFS were determined 136.94 mg CAE/kg oil, 227.35 mg/kg, 8.37 mg/kg, 2.22 mg/kg, 27.57 mg/kg, 8.82 mg/kg, 4.28 mg/kg, 7.96 h and 41.86 µmol TE/kg of oil, respectively. For the NGBDSS application TP, AT, BT, GT, TT, CH, CA, OS and DPPH AA values of olive oils were determined 65.93 mg CAE/kg oil, 239.49 mg/kg, 6.71 mg/kg, 3.07 mg/kg, 24.39 mg/kg, 6.87 mg/kg, 3.15 mg/kg, 6.76 h and 32.99 µmol TE/kg oil, respectively.

It was determined that the TP, BT, TT, CH, CA, OS and DPPH AA values of olive oil obtained from the TSFS application were higher than olive oils obtained from the NGBDSS application; however, the amount of AT and GT were lower.

It is thought that the reason why the TP, CH and CA amounts, OS, and DPPH AA values are higher in olive oil obtained from TSFS application compared to NGBDSS application, is due to the fact that the antioxidant properties of the leaves are transferred to olive oil due to the inability to extract the leaves sufficiently in this system.

Köseoğlu et al. [40] reported that Memecik olive oil's total phenol content was ranged from 79.66 to 222.18 mg CAE/kg oil in 2014/15 crop season. The total amount of phenol in olive oils obtained by adding 3% olive leaf to Tunisian olive varieties increased significantly with the addition of leaves [33]. Malheiro et al. [10] reported that in their study on olive oils obtained by adding different ratios of olive leaves to Cobrançosa olive fruit, the amount of α-tocopherol increased by approximately 30% in the oil obtained with the addition of 10% leaf, however, there was no difference in the amount of AT obtained with the addition of 5% leaf. He also reported that the value of the oxidative stability increased as the leaf addition rate increased, and this increase varied between 44% and 74% compared to the control sample. Köseoğlu et al. [41] stated that the OS of olive oils is particularly affected by the content of phenolic compounds, and Sevim [3] stated that the TP, AT, CH and DPPH AA value increase as the leaf addition rate increases. Farag et al. [42], Salta et al. [43] and Bouaziz et al. [39], many researchers found that the OS increased because of the addition of olive leaf or enrichment of edible vegetable oils with olive leaf extract. Gutierrez et al. [44] stated that phenolic compounds are responsible for approximately 50% of the oxidative stability of olive oils. Di Giovacchino et al. [32] stated that the amount of CH in the oils obtained by adding olive leaves at different rates increased as the leaf addition rate increased, while the TP and OS were not affected by the leaf addition rate. The increase in CH content improves the antioxidant properties of the oil when stored in the dark and consequently extends its shelf life [45]. Fabbri et al. [46] stated that phenolic compounds in olive leaves vary according to leaf age, branch type (weak, medium, strong), and variety, and the most important differences between compounds in leaves collected in May, July, and September vary according to variety and collection time.

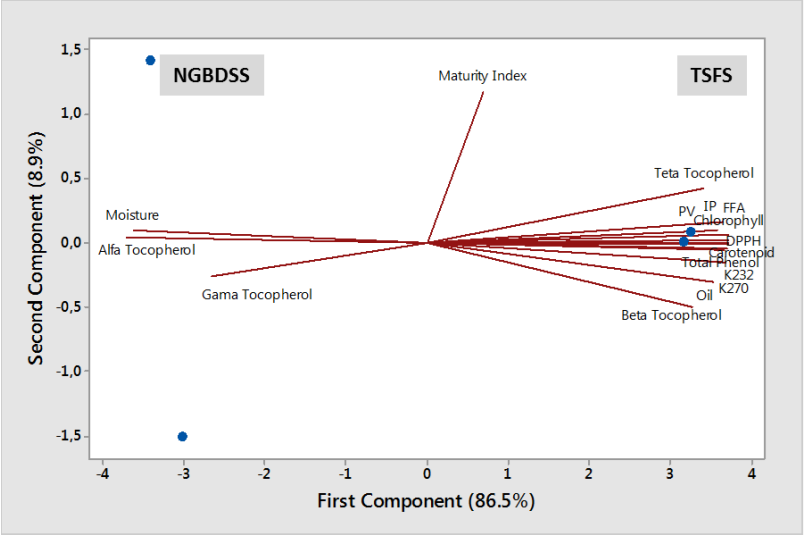

Figure 6. PCA biplot of oil samples according to olive analysis and quality parameters (TSFS: Traditional suction fan system, NGBDSS: New generation blown and drum sieve system)

According to olive analysis and quality parameters of oils, two groups were formed based on PCA analysis. PCA biplot was constructed with three components. The first principal component accounts for 86.5% of the total variance, while the second component accounts for 8.9%. As seen in the PCA biplot in Figure 6, olive oils obtained from olives treated with NGBDSS were also separated on the left top and bottom of the graph. TP, FFA, OS, DPPH AA, CH and CA, PV characterized TSFS samples placed on the right part of the plot.

Sensory Analysis

The sensory analysis results of the olive oils are shown in Figure 7. When the fruity, bitter, and pungent intensities of the olive oil samples were examined, it was determined that the olive oils obtained after the TSFS and NGBDSS application the fruity intensity was 4.50 and 4.40, the bitter intensity was 2.90 and 2.70, and the pungency was 4.00 and 3.90, respectively.

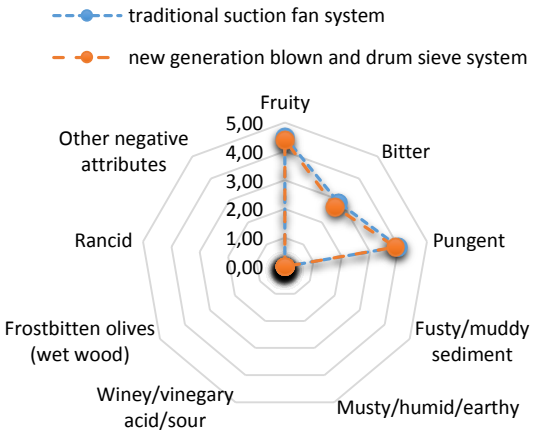

Figure 7. Sensory analysis results of olive oil samples (intensity)

As shown in Figure 7, no defects were detected in the olive oils obtained after applying TSFS and NGBDSS. It was determined that the fruity, bitter, and pungent intensities of the olive oils obtained from both applications were similar.

Volatile Compounds Analysis of Olive Oils

The results of the volatile compounds analysis of olive oils obtained from TSFS and NGBDSS application are shown in Table 5.

Table 5. Volatile compounds analysis results of olive oil samples (area)

No	Traditional suction fan system (TSFS)	Area	No	New generation blown and drum sieve system (NGBDSS)	Area
1	Hexanal	5751127	1	2-Hexenal	1455471
2	2-Hexenal	57193300	2	Copaene	248736
3	2-Octene	754749	3	Alpha farnasene	103565
4	1,6-Heptadiene	2331308	4	1,2-Benzenedicarboxylic acid	89468
5	Octanal	516901	5	1-Tetradecanamine	2274824
6	3-Hexen-1-ol	4377768	6	Morpholine	1172297
7	Acetic acid	1926048			
8	Beta-ocimene	1028946			
9	Nonanal	2355736			
10	Furan	605874			
11	2-Dodecene	512522			
12	Copaene	1898600			
13	Alpha farnacene	713616			

Thirteen volatile compounds were determined by application of TSFS, namely hexanal, 2-hexenal, 2-octene, 1,6-heptadiene, octanal, 3-hexene-1-ol, acetic acid, beta-ocimene, nonanal, furan, 2-dodecene, copaen and alpha farnacene. 6 volatile compounds, namely 2-hexenal, copaen, alpha farnacene, 1,2-benzenedicarboxylic acid, 1-tetradecanamine and morpholin, were determined in olive oil obtained by application NGBDSS.

It is thought that the reason why volatile compounds are higher in olive oil obtained after TSFS application is due to the fact that the leaves are not sufficiently extracted in this system, and that the volatile compounds of the leaves are transferred to olive oil more.

The primary volatile compound was hexanal, which is the main C6 volatile compound, which occurs because of the autoxidation of linoleic acid in the lipoxygenase pathway. The second dominating volatile compound

was cis-3-hexen-1-ol, which accounts for the elicitation of bitter sensations. The group of aldehydes was followed by alcohols and hydrocarbons [47].

Di Giovacchino et al. [32] reported that 1-3% leaf addition to olives caused an increase in the content of volatile compounds such as trans-2-hexenal, hexanal, 1-hexanol, cis-3-hexenol of olive oil. Malheiro et al. [38] stated that it causes an increase in the content of volatile compounds such as (E)-2-hexenal, (Z)-3-hexenal, (Z)-3-hexyl acetate.

CONCLUSION

The use of mechanical devices in the olive harvest causes an increase in the amount of foreign matter in the harvested product. Olives need to be cleaned effectively to both protect the oil quality and prevent damage to machinery by non-olive materials. Traditional leaf separation systems used for cleaning foreign materials in olives are sometimes insufficient for cleaning olives. For this reason, an innovative sorting/cleaning prototype has been developed to provide a more effective cleaning. By providing a more effective cleaning at this stage, the wear of tools and equipment during the production phase is prevented. With this study, we determined the efficiency, oil yield, olive oil quality and composition of the innovative sorting/cleaning machine and traditional cleaning machine.

Compared to the quality criteria, it has been determined that olive oil obtained after the application of TSFS and the NGBDSS has been classified as Virgin Olive Oil according to the Turkish Food Codex Olive Oil and Pomace Oil Communiqué. It was determined that the TP, CH and CA amounts, OS, and DPPH AA values of olive oil obtained from TSFS application were higher than olive oils obtained from NGBDSS application; however, the amount of α-tocopherol was lower. As a result, we can say that the components showing antioxidant properties were found to be higher in the olive oil obtained from the TSFS application.

When the fatty acid composition values of the olive oils obtained after the TSFS and the NGBDSS application were examined, it was determined that the fatty acid composition of the olive oils obtained from both applications was similar. In terms of volatile compounds, our study determined that there are 13 volatile compounds in the olive oil obtained after the application of the TSFS, and there are 6 volatile components in the olive oil obtained with the application of the NGBDSS. When the sensory properties of olive oils were analyzed, it was determined that the olive oils obtained from both applications are similar to the fruitiness, bitterness, and pungency of the olive oils obtained after applying an NGBDSS.

DECLARATION OF COMPETING INTERESTS

The authors declare no conflicts of interest.

ACKNOWLEDGMENTS

This project was undertaken by HAUS Machinery Industry and Trade Company. It was carried out in cooperation with İzmir Olive Research Institute of the Ministry of Agriculture and Forestry. It was supported by the General Directorate of Agricultural Research and Policy (TAGEM/18/ARGE/27).

REFERENCES

[1] Anonymous. (2017). Türk Gıda Kodeksi Zeytinyağı ve Pirina Yağı Tebliği (Tebliğ No: 2017/26), Ankara.

[2] Aydın, S., Özkan, G., Yorulmaz, A. (2020). Çeşit, olgunluk ve yoğurma şartlarının zeytinyağının sterol profili üzerine etkisi. *Akademik Gıda* 18(1), 87-95.

[3] Sevim, D. (2011). Zeytin Yaprağı Ilave Edilerek Elde Edilen Zeytinyağlarının Bazı Temel Kalite Kriterleri ve Antioksidan Aktivitelerinin Belirlenmesi. Doktora Tezi. Ege Üniversitesi Fen Bilimleri Enstitüsü, İzmir.

[4] Sevim, D., Dıraman, H., Köseoğlu, O., Büyükgök, E.B. (2017). Zeytinyağı üretim aşamaları, Bölüm: 5, Sofralık Zeytin ve Zeytinyağı Teknolojisi. İzmir.

[5] Servili, M., Monteedoro, G. (2002). Contribution of phenolic compounds to virgin olive oil quality. *European Journal of Lipid Science and Technology.* 104, 602-613.

[6] Dag, A., Kerem, Z., Yogev, N., Zipori, I., Lavee, S., Ben-David, E. (2011). Influence of time of harvest and maturity index on olive oil yield and quality. *Scientia Horticulturae,* 127, 358–366.

[7] Ocakoglu, D., Tokatlı, F., Ozen, B., Korel, F. (2009). Distribution of simple phenols, phenolic acids and flavanoids in Turkish monovarietal extra virgin olive oils for two harvest years. *Food Chemistry,* 113, 401-410.

[8] Sevim, D., Köseoğlu, O., Çetin, Ö., (2016). Bazı önemli zeytin çeşitlerinden elde edilen yağların minör bileşenlerinin ve antioksidan aktivitesinin belirlenmesi. *Zeytin Bilimi,* 6 (1), 1-7.

[9] Ilyasoglu, H., Ozcelik, B., Van Hoed, V., Verhe, R. (2010). Characterization of Aegean olive oils by their minor compounds. *Journal of the American Oil Chemists' Society*, 87, 627-636.

[10] Malheiro, R., Casal, S., Teixeria, H., Bento, A., Pereira, J.A. (2013). Effect of olive leaves addition during the extraction process of over mature fruits on olive oil quality. *Food Bioprocess Technology,* 6, 509-521.

[11] Clodoveo, M.L., Hbaieb, R.H., Kotti, F., Mugnozza, G.S., Gargouri, M. (2014). Mechanical strategies to increase nutritional and sensory quality of virgin olive oil by modulating the endogenous enzyme activities. *Comprehensive Reviews in Food Science and Food Safety,* 13, 135-154.

[12] International Olive Council (IOC) (1991). Zeytinyağı kalitesinin iyileştirilmesi. Yağ Teknolojisi Deneme Enstitüsü, İtalya.

[13] Türk Standartları Enstitüsü (TSE). (2020). TS EN ISO 665, Yağlı tohumlar- rutubet ve uçucu madde muhtevasının tayini, Ankara.
[14] Türk Standartları Enstitüsü (TSE). (2010). TS EN ISO 659, Yağlı tohumlar - yağ muhtevasının tayini (Referans Yöntem), Ankara.
[15] Anonymous (Turkish Food Codex) (2014). Türk Gıda Kodeksi Zeytinyağı ve Pirina Yağı Analiz Metotları Tebliği (Tebliğ No: 2014/53), Ankara.
[16] International Olive Council (IOC). (2017). Determination of fatty acid methyl esters by gas chromatography method COI/T.20/DOC. 33/Rev. 1.
[17] Carpenter, A.P. (1979). Determination of tocopherols in vegetable oils. *Journal of the American Oil Chemists' Society,* 59, 668-671.
[18] Dabbou, S., Isaaoui, M., Servili, M., Taticchi, A., Sifi, S., Montedoro, F.G., Hammami, M. (2008). Characterization of virgin olive oils from European olive cultivars introduced in Tunisia. *European Journal of Lipid Science and Technology*, 111(4), 392-401.
[19] IUPAC. (1992). Standard Methods for the Analysis of Oils, Fats and Derivates, Methods 2.432 (7th ed.)
[20] Gutfinger, T. (1981). Polyphenols in olive oils. *Journal of the American Oil Chemists' Society,* 58, 966-968.
[21] Hrncirik, K., Fritsche, S. (2004). Comparability and reliability of different techniques for the determination of phenolic compounds in virgin olive oil. *European Journal of Lipid Science and Technology*, 106, 540-549.
[22] Jiang, L., Yamaguchi, T., Takamura, H., Matoba, T. (2005). Characteristics of Shodo Island olive oils in Japan: fatty acid composition and antioxidative compounds. *Food Science and Technology Research,* 18(11), 254-260.
[23] Carrasco-Pancorbo, A., Cerretani, L., Bendini, A., Segura-Carretero, A., Del Carlo, M., Gallina-Toschi, T., Lercker, G., Compagnone, D., Fernandez-Gutierrez, A. (2005). Evaluation of the antioxidant capacity of ındividual phenolic compounds in virgin olive oil. *Journal of Agricultural and Food Chemistry*, 53, 8918-8925.
[24] Lavelli, V. (2002). Comparison of the antioxidant activities of extra virgin olive oils. *Journal of Agricultural and Food Chemistry*, 50(1), 7704-7708.
[25] Tura, D., Gigliotti, C., Pedò, S., Failla, O., Bassi, D., Serraiocco, A. (2007). Influence of cultivar and site of cultivation on levels of lipophilic and hydrophilic antioxidants in virgin olive oils (*Olea europea* L.) and correlations with oxidative stability. *Scientia Horticulturae,* 112, 108-119.
[26] Minguez-Mosquera, M.I., Rejano, L., Gandul, B., Sanchez A.H., Garrido, J. (1991). Color-pigment correlation in virgin olive oil. *Journal of American Oil Chemistry Society*, 68, 332-336.
[27] IOC. (2018) Sensory analysis of olive oil – method for the organoleptic assessment of virgin olive oil, COI/T.20/Doc. No 15/Rev. 10/2018.
[28] Yorulmaz, A., Yıldırım, A., Duran, M., Kula, O., Kıvrak, M. (2016). Impact of malaxation on quality and compositional characteristics of Edremit Yağlık olive oil. *Journal of Food Processing and Preservation*, 41(6), e13291.
[29] Boskou, D. (1996). Olive oil chemistry and technology history and characteristics of the olive oil tree. AOCS Press, Champaign, Illinois, 1-6.
[30] Bartolucci, P., Dhakal, B.R. (1999). Prospects for olive growing in Nepal. FAO, Kathmandu, TPC/NEP/6713.
[31] Gibriel, A.Y., Abd El-Rahman, H.A., Abd El-Razik Ali, F., Abou-Zaid, F.O. (2004). Effect of olive leaves addition and wastewater recycling on the productivity and quality of olive oil produced by centrifugation. 7th World Congress and Recovery, Recycling and Re-Integration, 1-5.
[32] Di Giovacchino, L., Angerosa, F., Di Giacinto, L. (1996). Effect of mixing leaves with olives on organoleptic quality of oil obtained by centrifugation. *Journal of the American Oil Chemists' Society,* 73(3), 371-374.
[33] Tarchoune, I., Sgherri, C., Eddouzi, J., Zinnai, A., Quartacci, M.F., Zarrouk, M. (2019). Olive leaf addition ıncreases olive oil nutraceutical properties. *Molecules,* 24, 545, 1-15.
[34] Di Giovacchino, L., Sestili, S., Di Vincenzo, D. (2002). Influence of olive processing on virgin olive oil quality, *European Journal of Lipid Science and Technology,* 104, 587-601.
[35] Bıyıklı, K. (2009). Türk zeytinyağlarının saflık derecelerinin belirlenmesi. Yüksek Lisans Tezi, FBE, Ankara Üniversitesi, Ankara.
[36] İlyasoğlu, H. (2009). Ayvalık ve Memecik zeytinyağlarının coğrafi isaretleme amacıyla karakterizasyonu. İTÜ, Doktora Tezi, FBE, İstanbul.
[37] Dıraman, H., Dibeklioğlu. H (2014). Using lipid profiles for the characterization of Turkish monocultivar olive oils produced by different systems. *International Journal of Food Properties.* 17 (5), 1013-1033.
[38] Malheiro, R., Rodrigues, N., Bissaro, C., Leimann, F., Casal, S., Ramalhosa, E., Alberto Pereira, J. (2017). Improvement of sensorial and volatile profiles of olive oil by addition of olive leaves. *European Journal of Lipid Science and Technology,* 119, 1-11.
[39] Bouaziz, M., Fki, I., Jemaı, H., Ayadi, M., Sayadi, S. (2008). Effect of storage on refined and husk olive oils composition: stabilization by addition of natural antioxidants from Chemlali olive leaves. *Food Chemistry,* 108 (1), 253-262.
[40] Köseoğlu, O., Sevim, D., Ulaş, M., Özdemir, D. (2018). Determination of bitterness index (K225) and total phenol content of olive oils obtained with different regions, varieties and processing systems. *Ege Journal Agricultural Research,* 55(2), 171-178.
[41] Köseoğlu, O., Sevim, D., Kadiroğlu, P. (2016). Quality characteristics and antioxidant properties of Turkish monovarietal olive oils regarding stages of olive ripening. *Food Chemistry,* 212, 628-634.
[42] Farag, R.S., El-Baroty, G.S., Basuny, A.M. (2003). The influence of phenolic extracts obtained from the olive plant (Cvs. Picual and Kronakii), on the stability of sunflower oil. *International Journal of Food Science and Technology,* 38, 81-87.

[43] Salta, F.N., Mylona, A., Chiou, A., Boskou, G., Andrikopoulos, N.K. (2007). Oxidative stability of edible vegetable oils enriched in polyphenols with olive leaf extract. *Food Science and Technology International,* 13 (6), 413-42.

[44] Gutierrez, F., Arnaud, T., Garrido, A. (2001). Contribution of polyphenols to the oxidative stability of virgin olive oil. *Journal Science of Food and Agriculture,* 81, 1463-1470.

[45] Novoselic, A., Klisovic, D., Lukic, I., Lukic, M., Brkic Bubola, K. (2021). The use of olive leaves in Buža olive cultivar oil production: exploring the ımpact on oil yield and chemical composition. *Agriculture,* 11, 917.

[46] Fabbri, A., Galaverna, G., Ganino, T. (2008). Polyphenol composition of olive leaves with regard to cultivar, time of collection and shoot type. *Acta Horticulturae,* 791, 459-464.

[47] Kula, Ö., Yıldırım, A., Yorulmaz, A., Duran, M., Mutlu, İ., Kıvrak, M. (2018). Effect of crushing temperature on virgin olive oil quality and composition. *Grasas Aceites*, 69(1), e239.