

Evaluating the Fatty Acid, Sterol and Erythrodiol+Uvaol Contents of Turkish Olive Oil under Different Maturity Index and Storage Conditions with Chemometric Approaches

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Abstract

The objective of this study was to utilize unsupervised classification and clustering techniques, such as hierarchical (HCA) and principal component analyses (PCA), to assess the impact of maturity index and storage conditions on the composition of fatty acids, sterols, and erythrodiol+uvaol in Ayvalık and Memecik Turkish extra virgin olive oils. For a period of 15 months, the oils were maintained at ambient temperature, under daylight conditions, and in darkness within two transparent glass bottles. The chemometric analysis yielded the revelation that both Memecik and Ayvalık could be classified into two distinct subgroups. The findings indicated that oleic, behenic, arachidic, gadoleic, and MUFA (Monounsaturated Fatty Acid) acids were pivotal in distinguishing the initial harvest year for both oils. The second year's characterization process involved the analysis of palmitic, palmitoleic, heptadecanoic, heptadecenoic, trans fatty acids, SFA (Saturated Fatty Acids), and MUFA in the Ayvalık olive oil; and miristic, linolenic, and PUFA (Polyunsaturated Fatty Acids) in the Memecik olive oil. The results of the PCA indicate that Memecik oils contain β -sitosterol, stigmasterol, cholesterol, clerosterol, brassicasterol, and erythrodiol+uvaol, while Ayvalık oils contain campestanol, sitosterol, campestanol, $\Delta 7$ -avenasterol, $\Delta 5$ -avenasterol, total sterol, $\Delta 5$ -7 stigmastadienol, and total β -sitosterol.

Key words: PCA, HCA, Sterol, Fatty acid, Storage conditions.

Farklı Olgunluk İndeksi ve Depolama Koşullarında Türk Zeytinyağlarının Yağ Asidi, Sterol ve Eritrodiol+Uvaol İçeriklerinin Kemometrik Yaklaşımlarla Değerlendirilmesi

Özet

Bu çalışmanın amacı, Ayvalık ve Memecik Türk sızma zeytinyağında olgunluk indeksi ve saklama koşullarının yağ asitleri, steroller ve eritrodiol+uvaol bileşimi üzerindeki etkisini değerlendirmek için hiyerarşik (HCA) ve temel bileşen analizleri (PCA) gibi denetimsiz sınıflandırma ve kümeleme tekniklerinden yararlanmaktır. Yağlar 15 ay süreyle oda sıcaklığında, gün ışığı koşullarında ve karanlıkta iki şeffaf cam şişe içerisinde muhafaza edildi. Kemometrik analiz, Memecik ve Ayvalık'ın iki ayrı alt gruba ayrılabilmesini ortaya çıkardı. Bulgular, oleik, behenik, araşidik, gadoleik ve MUFA asitlerinin, her iki yağ için de ilk hasat yılını ayırt etmede çok önemli olduğunu gösterdi. İkinci yılın karakterizasyon sürecinde Ayvalık zeytinyağında palmitik, palmitoleik, heptadekanoik, heptadekenoik, trans yağ asitleri, SFA ve MUFA analizleri; Memecik zeytinyağında miristik, linolenik ve PUFA bulunur. PCA sonuçları Memecik yağlarının β -sitosterol, stigmasterol, kolesterol, klerosterol, brassicasterol ve eritrodiol+uvaol içerdiğini, Ayvalık yağlarının ise kampestanol, sitosterol, kampestanol, $\Delta 7$ -avenasterol, $\Delta 5$ -avenasterol, toplam sterol, $\Delta 5$ -7 stigmastadienol ve toplam β -sitosterol içerdiğini göstermektedir.

Anahtar kelimeler: PCA, HCA, Sterol, Yağ asidi, Depolama koşulları.

Introduction

An economic and social perspective places great importance on olive farming and the olive oil industry, particularly in Spain, Italy, Türkiye, Portugal and Greece (López-Salas et al., 2024). In Türkiye, the majority of olive production is concentrated in a small number of varieties (well known local olive fruits include Ayvalık, Memecik, Gemlik, Domat, Erkence, Nizip Yağlık etc.), although the Turkish National Germplasm Bank has registered 95 distinct endemic varieties (Yıldırım et al., 2023). In the context of Turkish olive cultivation, Ayvalık and Memecik cultivars have emerged as predominant, economically significant, and widely adopted varieties. These cultivars collectively contribute to a substantial proportion of the nation's total olive oil production, accounting for

approximately 75-80% of the total output (Sevim and Tuncay, 2013).

A substantial body of research has been conducted on the dietary and medicinal qualities of olive oil, and the results of these studies have been thoroughly documented. Historically, the primary benefits of oil consumption have been ascribed to its abundant presence of monounsaturated fatty acids (MUFAs) (Peres et al., 2024). Olive oil is food that works well for preventing of cardiovascular, hypertension, cancer and digestive system diseases due to its monounsaturated fatty acids and antioxidant substances (López-Salas et al., 2024). A comprehensive analysis reveals that 98% of olive oil is composed of glycerides and fatty acids, which are predominant components, while 2% consists of minor components (IOC, 2022). An 3 of olive oil quality is conducted by means of a multifaceted

approach, incorporating a range of assessment techniques. Among these methods are organoleptic tests, which are utilized to identify and evaluate characteristics related to the sensory perception of the oil. Additionally, analyses of fatty acid composition are employed to ascertain the nutritional value and chemical profile of the olive oil. Furthermore, physicochemical parameters are measured to provide a comprehensive assessment of the oil's physical and chemical properties. To ensure the dietary value, authenticity, and purity of olive oils sold, it is imperative that monitoring be carried out in an effective and continuous manner. A comprehensive understanding of the fatty acid composition is imperative. The composition of fatty acids of olive oils serves as a crucial quality parameter and a reliable indicator of their authenticity. The composition of fatty acids of oil is influenced by numerous factors, including variety, maturity, and climate (Bechar et al., 2024; Köseoğlu et al., 2016). Palmitic, oleic, linoleic and stearic are major fatty acids, palmitoleic, linolenic and arachidonic are minor fatty acids. The oleic acid content of olive oil is 55-85%, linoleic acid content is 2.5-21% and linolenic acid content is below $\leq 1\%$ (IOC, 2022). The surrounding conditions have been demonstrated to exert an influence on the content of oleic and linoleic acids (Rodrigues et al., 2021). Olive oil is regarded as a stable and healthful fat, and due to its high proportion of monounsaturated fatty acids and low content of saturated fatty acids, it is an ideal fat source that can lower cardiovascular disease risk (Mousavi et al., 2019; Gagour et al., 2024). Vegetable oils' shelf life is shortened by oxidation, a significant process that alters their organoleptic characteristics. Oxidation alters various physiological properties as well as causing a loss of nutritional value (Bouaziz et al., 2008). Changes in the composition of fatty acids and the loss of smaller components are the main factors affecting the shelf life of olive oils. According to reports, about 24% of Rancimat stability is attributed to the composition of fatty acids (Mateos et al., 2003). The level of unsaturation of fatty acids and the existence of antioxidants such as phenolic compounds and carotenoids, among other factors, have an impact on the structure of olive oil and its ability to prevent autooxidation and photooxidation during storage (Bechar et al., 2024). Previous studies found that the content of palmitic acid in olive oils remained unchanged, while the content of unsaturated and saturated fatty acids decreased, increased, and oleic acid decreased due to oxidation (Mendez and Falque, 2007). Moreover, the content of stearic acid increased (Morello et al. 2004; Mendez and Falque, 2007), oleic acid increased, linoleic and linolenic acid decreased, and oleic acid increased because of the decrease in polyunsaturated fatty acids like linoleic and

linolenic acid due to degradation and preservation of the content of saturated fatty acids (Morello et al., 2004). According to Gomez-Alonso et al. (2007), linolenic acid content decreased more during the storage period than linoleic acid content. This was because, under the same oxidation conditions, the antioxidants in extra virgin olive oil protected linoleic acid greater than linolenic acid.

Sterols are essential for human nutrition and health. The majority of the unsaponifiable material in olive oil is made up of phytosterols, which are sterols that are present in vegetables and plant oils. Plant species are characterized by their sterol profiles. Understanding the makeup of sterols is crucial for determining the nutritional value and identity of olive oil. The composition and amount of sterols are important factors in determining the quality of extra virgin olive oil. These substances are some of the most important criteria for trade standards that are used to confirm the legitimacy of olive oil and identify counterfeiting (Piravi-Vanak et al., 2012). Sterols, on the other hand, show a lot of promise as practical chemical markers to guarantee the variety, traceability, and geographic origin of olive oil (Lukić et al., 2021; Sevim et al., 2023). Olive oil's primary sterols are β -sitosterol, delta-5-avenasterol, and campesterol. Others include stigmasterol, cholesterol, and related compounds. β -Sitosterol makes up most (75-90%) of the total sterols in olive oil. The percentage of delta-5-avenasterol ranges between 5-20%, while campesterol and stigmasterol are between 1-4% and 0.5-2%, respectively. 24-methylene-cholesterol, which is found in low levels in the structure of olive oil, is an intermediate product in campesterol synthesis and is a characteristic component of olive pulp and is the only sterol in which significant differences can be clearly observed between varieties and ripening stages (Şahin et al., 2008). High levels of stigmasterol are an indication of high acidity and low sensory properties (Bıyıklı, 2009). Sterols are heat stable, odourless and tasteless compounds. The quantitative sterol profiles of olive fruits are recognized to be impacted by several factors. Genetics of fruit (Navas-Lopez et al., 2019), environment (soil, location, climate, water) (Hamze et al., 2022), fruit ripening stage (Giuffrè et al., 2013), harvest year (Rey-Giménez et al., 2022), the oils' storage conditions or technological factors (Guillaume et al., 2012) all have an impact on the composition of sterols. And also, recently it has been suggested to use sterol composition to categorize extra virgin olive oil based on fruit varieties (Rivera del A' lamo et al., 2004).

The objectives of this study were to assess the impact of ripening index and storage conditions on the fatty acids, sterol, and erythrodiol+uvaol contents of Turkish virgin olive oil. To this end, unsupervised chemometrics classification and

clustering methods, such as PCA and HCA, were utilized. Ayvalık and Memecik olive oils were stored in two distinct transparent glass bottles at ambient temperature in conditions of both daylight and darkness for a period of 15 months. Fatty acid, sterol, and erythrodiol+uvaol content analyses were conducted at five-month intervals (0 (initial), 5, 10, and 15 months).

Materials and Method

Material

The "Ayvalık" and "Memecik" varieties were harvested from orchards in Ayvalık and Aydın regions, respectively, in two consecutive harvest periods (Figure 1). The olives were harvested by hand at two different maturation indices and subsequently processed (without waiting) by an Abencor system at the Olive Research Institute of Turkish Ministry of Agriculture and Forestry in Izmir, Türkiye.

Method

Maturity index (MI)

Maturity index, which the International Olive Council's suggested approach (IOC, 1991), according to the olive skin's color and is determined by gathering about one kilogram of olives.

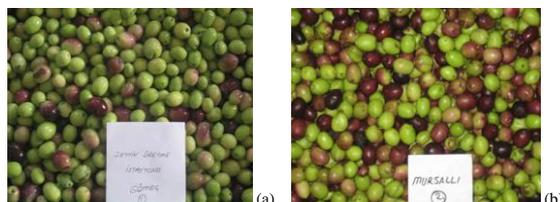


Figure 1. Ayvalık (a) and Memecik (b) cultivars
Şekil 1. Ayvalık (a) ve Memecik (b) çeşitleri

Oil extraction

The olives of the "Ayvalık" and "Memecik" were harvested manually. The fruits were thoroughly cleaned with tap water, followed by mechanical crushing using an Abencor System (MC2, Spain). The instrument is outfitted with apparatus designed for the compression of fruit, as well as mechanisms that facilitate the process of malaxating and centrifugal separation. Cold pressing was used in the process (25°C) and the olives were malaxing for approximately 30 minutes. The extracted oils were then separated into two distinct fractions. The objective of this step was to conduct a comprehensive investigation into the storage effects of daylight and darkness, as well as ambient temperature, over a period of 15 months. Fatty acid composition analysis was conducted at five-month intervals (0, 5, 10, and 15 months).

Fatty acid composition

According to IOC methods, the fatty acid composition was assessed, COI/T.20/Doc.No.33.Rev1 (IOC, 2017). Fatty acid methyl esters (FAMES) were examined using chromatography of gas with a flame ionization detector and an Agilent DB-23 capillary column. The temperature of the oven was kept constant between 170°C and 210°C for ten minutes at a 2 C min⁻¹ increase, the detector temperatures at 250 °C, the carrier gas at 0.5 ml min⁻¹, the injection volume at 0.2 µL, and the split ratio at 1:100. A standard FAME reference mixture (Sigma-Aldrich Chemicals 189-19) was used for reference. The area percentages of all fatty acids were determined and recorded using ChemStation software.

Sterol composition

Sterol and diol amounts were determined using the IOC method, COI/T.20/Doc. No 26 (IOC, 2020). The sterol fraction was analyzed with a Hewlett-Packard 6890 with a split injector and flame-ionization detector. 2 N ethanolic potassium hydroxide was used to saponify the olive oil after adding α -cholestanol. The unsaponifiable was extracted with ethyl ether. The analytical column was an HP-5 with a 5% phenyl, methyl, siloxane stationary phase (30m×0.32mm×0.25µm). The chromatographic conditions were as follows: temperature of an inlet: 280°C; temperature of an oven: 260°C; temperature of detector: 290°C; split ratio: 1:50; amount injected: 1µL. As a carrier gas, helium was utilized at a flow rate of 0.7 to 0.8 ml min⁻¹. Cholestanol served as an internal standard for the measurement of sterols. Outcomes for individual sterols were stated as percentages of total sterols. Total sterols were stated as percentages of total sterols and diols.

Statistical analysis

The olive oil samples were subjected to unsupervised chemometrics techniques, specifically PCA and HCA, to achieve multivariate classification and clustering. Using Minitab Statistical software version 15, multivariate analysis was carried out.

Results and Discussion

Figure 2 shows the maturity index of Ayvalık and Memecik olives. In the first harvest year, 1st MI of Ayvalık olives was 2.02 and 2nd MI was 2.33; in 2010, 1st MI of Ayvalık olives was 1.5 and 2nd MI was 2.2. In 2009, 1st MI of Memecik olives was 1.97 and 2nd MI was 2.83; in 2010, 1st MI of Memecik olives was 1.6 and 2nd MI was 2.3.

Ayvalık extra virgin olive oil, oleic acid varied between 68.13-69.22% and 66.24-67.20%, linoleic acid varied between 10.86-11.47% and 11.89-12.37%, linolenic acid varied between 0.64-0.72% and 0.70-0.74% was determined after 15 months of storage in the daylight conditions at the 1st MI, in

the first and the second harvest year, respectively. Also oleic acid varied between 68.13-69.73% and 66.65-67.20%, linoleic acid varied between 11.06-11.47% and 11.87-12.37%, linolenic acid varied between 0.65-0.72% and 0.69-0.74% was determined after 15 months of storage in the dark conditions at the 1st MI, in the first and the second harvest year, respectively.

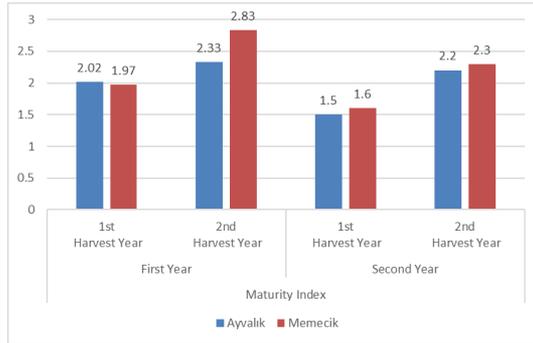


Figure 2. Maturity index of Ayvalık and Memecik cultivars

Şekil 2. Ayvalık ve Memecik çeşitlerinde olgunluk indeksi

When looked at the 2nd MI oleic acid varied between 69.29-69.99% and 65.98-66.65%, linoleic acid varied between 10.47-11.42% and 12.71-12.99%, linolenic acid varied between 0.62-0.74% and 0.71-0.77% was determined after 15 months of storage in the daylight conditions, in the first and the second harvest year, respectively. Also oleic acid varied between 69.07-69.73% and 66.05-66.46%, linoleic acid varied between 10.89-11.42% and 12.85-12.96%, linolenic acid varied between 0.66-0.74% and 0.74-0.77% was determined after 15 months of storage in the dark conditions at the 2nd MI, in the first and the second harvest year, respectively. Memecik extra virgin olive oil, oleic acid varied between 71.43-72.70% and 65.21-65.70%, linoleic acid varied between 9.14-9.83% and 13.21-13.66%, linolenic acid varied between 0.80-0.89% and 0.92-0.95% was determined after 15 months of storage in the daylight conditions at the 1st MI, in 2009 and 2010, respectively. Also oleic acid varied between 71.43-72.33% and 65.39-66.16%, linoleic acid varied between 9.14-9.71% and 12.91-13.40%, linolenic acid varied between 0.81-0.89% and 0.85-0.94% was determined after 15 months of storage in the dark conditions at the 1st MI, in the first and the second harvest year, respectively. When looked at the 2nd MI oleic acid varied between 69.81-70.33% and 67.27-67.57%, linoleic acid varied between 10.81-11.00% and 13.08-13.28%, linolenic acid varied between 0.80-0.91% and 0.85-0.86% was determined after 15 months of storage in the daylight conditions, in the first and the second harvest year, respectively. Also

oleic acid varied between 69.47-70.74% and 67.14-67.70%, linoleic acid varied between 10.70-11.09% and 12.94-13.22%, linolenic acid varied between 0.83-0.91% and 0.81-0.88% was determined after 15 months of storage in the dark conditions at the 2nd MI, in the first and the second harvest year, respectively.

The primary elements of extra virgin olive oil's stability are its antioxidants and composition of fatty acid. Oxidation of fats, particularly when trace metals are present, is one of the main storage degradations. Lipid peroxide is formed when unsaturated fatty acid double bonds are attacked by reactive oxygen radicals. In the study, no significant change was detected in the fatty acid composition during 15 months of storage in both daylight and dark conditions, and it followed an uneven course. The fatty acid composition of Ayvalık and Memecik oils remained within the limits set by the IOC trading standard (IOC, 2022) throughout the shelf life and was determined as virgin olive oil. Similar outcomes were attained in different studies. Gagour et al. (2024) reported that extra virgin olive oil can be stored for up to two years without losing its sensory qualities if it is kept in appropriate and well-made packaging. Mendez and Falque (2007) reported that the unsaturated fatty acid content of olive oils and the oleic acid content decreased due to oxidation during storage, Morello et al. (2004) reported that the oleic acid content increased due to the decrease in polyunsaturated fatty acids such as linoleic acid and linolenic acid due to deterioration and the preservation of the saturated fatty acid content, Gomez-Alonso et al. (2007) reported that the decrease in linolenic acid content during storage was greater than the linoleic acid content, and this was due to the antioxidants of virgin olive oil protecting linoleic acid more than linolenic acid under the same oxidation conditions. It was determined that heptadecanoic acid, heptadecenoic acid, linoleic acid, SFA and PUFA contents were lower in Memecik olive oil than in Ayvalık olive oil, while oleic acid, linolenic acid and MUFA contents were higher. The findings concerning the fatty acid composition of Memecik and Ayvalık olive oils were discovered to be in agreement with previous research (Andjelkovic et al., 2009; İlyasoğlu and Özçelik, 2011; Köseoğlu et al., 2016) reached similar conclusions in their studies.

Table 1. The composition of fatty acids (%) in Ayvalık (A) and Memecik (M) olive oils at different MI in daylight and dark, in the first harvest year during 15 months storage

Çizelge 1. Ayvalık (A) ve Memecik (M) zeytinyağlarının farklı MI değerlerinde, birinci hasat yılında, gün ışığında ve karanlıkta, 15 aylık depolama süresince yağ asitleri kompozisyonları (%)

MI	V	ST	STP	C14:0	C16:0	C16:1	C17:0	C17:1	C18:0	C18:1	C18:2T	C18:2	18:3T	C18:3	C20:0	C20:1	C22:0	C24:0	SFA	MUFA	PUFA
1	A	DL	0	0.02	14.35±0.01	1.06	0.14	0.25	2.24	68.13±0.01	0.02	11.47±0.01	0.05	0.72	0.47	0.35	0.16	0.08	17.46	69.53±0.03	12.19
			5	0.02	13.93±0.02	1.04	0.14	0.25	2.25	69.23±0.00	0.01	11.38±0.01	0.04	0.71	0.47	0.35	0.15	0.08	17.04	70.87±0.04	12.08
			10	0.02	14.64±0.00	1.09	0.14	0.25	2.24	68.41±0.04	0.02	11.44±0.00	0.04	0.72	0.44	0.32	0.14	0.07	17.70	70.08±0.05	12.15
			15	0.02	14.50±0.01	1.00	0.14	0.24	2.30	69.22±0.02	0.00	10.86±0.01	0.00	0.64	0.47	0.35	0.16	0.08	17.67	70.80±0.04	11.50
1	A	D	0	0.02	14.35±0.03	1.06	0.14	0.25	2.24	68.13±0.02	0.02	11.47±0.02	0.05	0.72	0.47	0.35	0.16	0.08	17.46	69.53±0.03	12.19
			5	0.02	13.95±0.01	1.07	0.14	0.25	2.24	69.31±0.01	0.02	11.34±0.03	0.04	0.70	0.47	0.35	0.16	0.08	17.06	70.98±0.03	12.04
			10	0.02	14.81±0.02	1.09	0.14	0.25	2.23	68.36±0.01	0.01	11.31±0.04	0.04	0.71	0.45	0.33	0.14	0.07	17.86	70.04±0.04	12.02
			15	0.02	14.22±0.02	1.02	0.14	0.24	2.35	69.16±0.00	0.00	11.06±0.00	0.00	0.65	0.49	0.36	0.16	0.08	17.46	70.79±0.03	11.70
2	A	DL	0	0.02	13.04±0.01	0.96	0.14	0.24	2.37	69.73±0.01	0.01	11.42±0.02	0.05	0.74	0.52	0.38	0.20	0.11	16.40	71.04±0.04	12.16
			5	0.02	13.69±0.01	0.99	0.14	0.25	2.33	69.40±0.04	0.01	11.33±0.01	0.05	0.72	0.47	0.34	0.16	0.08	16.88	70.98±0.03	12.06
			10	0.02	13.73±0.02	1.00	0.15	0.25	2.33	69.29±0.02	0.01	11.37±0.01	0.05	0.74	0.47	0.34	0.16	0.07	16.92	70.88±0.03	9.78
			15	0.02	13.85±0.02	0.94	0.16	0.24	2.53	69.99±0.03	0.00	10.47±0.01	0.00	0.62	0.53	0.37	0.18	0.08	17.36	71.54±0.04	11.09
2	A	D	0	0.02	13.04±0.01	0.96	0.14	0.24	2.37	69.73±0.01	0.01	11.42±0.02	0.05	0.74	0.52	0.38	0.20	0.11	16.40	71.04±0.04	12.16
			5	0.02	13.72±0.01	0.99	0.15	0.25	2.33	69.27±0.02	0.01	11.30±0.02	0.05	0.72	0.48	0.34	0.16	0.08	16.94	70.85±0.04	12.01
			10	0.02	14.07±0.03	1.01	0.15	0.25	2.33	69.07±0.01	0.01	11.25±0.01	0.05	0.72	0.47	0.34	0.15	0.07	17.27	70.66±0.03	9.86
			15	0.02	13.95±0.01	0.97	0.15	0.25	2.43	69.58±0.01	0.00	10.89±0.00	0.00	0.66	0.49	0.35	0.16	0.07	17.28	71.15±0.04	11.55

MI: Maturity Index, V: Variety, ST: Storage Type, STP: Storage Period (Month), Myristic (C14:0), Palmitic (C16:0), palmitoleic (C16:1), Margaric (C17:0), Margoleic (C17:1), Stearic (C18:0), Oleic (C18:1), Linoleic (C18:2), Linolenic (C18:3), Arachidic (C20:0), Gadoleic (C20:0), Behenic (C22:0), Lignoceric (C24:0), Saturated Fatty Acids (SFA), Monounsaturated fatty acids (MUFA), Polyunsaturated fatty acids (PUFA).

MI: Olgunluk İndeksi, V: Çeşit, ST: Depolama Tipi, STP: Depolama Süresi (Ay), Miristik (C14:0), Palmitik (C16:0), Palmitoleik (C16:1), Margarik (C17:0), Margoleik (C17:1), Stearik (C18:0), Oleik (C18:1), Linoleik (C18:2), Linolenik (C18:3), Arakidik (C20:0), Gadoleik (C20:0), Behenik (C22:0), Lignoserik (C24:0), Doymuş Yağ Asitleri (SFA), Tekli Doymamış Yağ Asitleri (MUFA), Çoklu Doymamış Yağ Asitleri (PUFA).

Table 1 The composition of fatty acids (%) in Ayvalık (A) and Memecik (M) olive oils at different MI in daylight and dark, in the first harvest year during 15 months storage (continued)

Çizelge 1. Ayvalık (A) ve Memecik (M) zeytinyağlarının farklı MI değerlerinde, birinci hasat yılında, gün ışığında ve karanlıkta, 15 aylık depolama süresince yağ asitleri kompozisyonları (%) (devamı)

MI	V	ST	STP	C14:0	C16:0	C16:1	C17:0	C17:1	C18:0	C18:1	C18:2T	C18:2	18:3T	C18:3	C20:0	C20:1	C22:0	C24:0	SFA	MUFA	PUFA		
1	M	DL	0	0.02	13.33±0.01	1.02	0.04	0.07	2.09	71.43±0.01	0.02	9.14±0.02	0.01	0.88	0.44	0.36	0.15	0.07	16.15	72.94±0.04	10.02		
			5	0.02	12.36±0.01	1.01	0.04	0.07	2.05	72.70±0.01	0.01	9.83±0.00	0.01	9.83±0.00	0.01	0.89	0.43	0.36	0.14	0.07	15.11	74.15±0.03	10.73
			10	0.02	13.68±0.02	1.02	0.05	0.07	2.09	71.44±0.00	0.02	9.69±0.01	0.01	9.69±0.01	0.01	0.88	0.43	0.35	0.14	0.07	16.47	72.89±0.03	11.01
			15	0.02	13.02±0.00	0.96	0.04	0.07	2.15	72.41±0.01	0.00	9.46±0.01	0.00	9.46±0.01	0.00	0.80	0.46	0.37	0.14	0.08	15.90	73.82±0.04	10.26
1	M	D	0	0.02	13.33±0.01	1.02	0.04	0.07	2.09	71.43±0.02	0.02	9.14±0.02	0.01	0.88	0.44	0.36	0.15	0.07	16.15	72.94±0.04	10.02		
			5	0.02	12.84±0.03	1.00	0.04	0.07	2.08	72.33±0.03	0.01	9.62±0.02	0.01	9.62±0.02	0.01	0.88	0.45	0.37	0.14	0.08	15.65	74.08±0.05	10.50
			10	0.02	13.43±0.01	1.02	0.04	0.07	2.10	71.60±0.00	0.02	9.71±0.03	0.01	9.71±0.03	0.01	0.89	0.44	0.36	0.14	0.07	16.25	73.05±0.04	10.87
			15	0.02	13.32±0.01	0.98	0.04	0.07	2.18	72.08±0.01	0.00	9.41±0.01	0.00	9.41±0.01	0.00	0.81	0.46	0.37	0.15	0.07	16.25	73.50±0.03	10.22
2	M	DL	0	0.02	12.94±0.00	1.03	0.05	0.07	2.54	70.33±0.01	0.02	11.00±0.00	0.01	0.89	0.50	0.36	0.15	0.07	16.27	71.50±0.04	11.89		
			5	0.02	13.26±0.01	1.06	0.05	0.07	2.48	70.02±0.00	0.02	11.09±0.02	0.01	11.09±0.02	0.01	0.90	0.47	0.33	0.14	0.06	16.48	71.49±0.03	11.99
			10	0.02	13.49±0.02	1.07	0.05	0.07	2.49	69.81±0.01	0.02	11.04±0.02	0.01	11.04±0.02	0.01	0.91	0.46	0.33	0.13	0.06	16.70	71.28±0.04	11.95
			15	0.02	13.34±0.03	1.02	0.05	0.07	2.59	70.23±0.02	0.00	10.81±0.01	0.00	10.81±0.01	0.00	0.80	0.50	0.36	0.15	0.07	16.71	71.67±0.03	11.61
2	M	D	0	0.02	12.94±0.01	1.03	0.05	0.07	2.54	70.33±0.01	0.02	11.00±0.01	0.01	0.89	0.50	0.36	0.15	0.07	16.27	71.50±0.04	11.89		
			5	0.02	12.54±0.02	1.05	0.04	0.07	2.39	70.74±0.00	0.01	11.08±0.01	0.01	11.08±0.01	0.01	0.90	0.46	0.34	0.13	0.06	15.65	72.19±0.04	11.98
			10	0.03	13.78±0.01	1.11	0.05	0.07	2.47	69.47±0.01	0.02	11.09±0.00	0.01	11.09±0.00	0.01	0.91	0.45	0.32	0.13	0.06	16.95	70.98±0.05	12.00
			15	0.02	13.31±0.02	1.02	0.05	0.07	2.61	70.31±0.02	0.00	10.70±0.00	0.00	10.70±0.00	0.00	0.83	0.50	0.36	0.15	0.07	16.69	71.77±0.05	11.53

MI: Maturity Index, V: Variety, ST: Storage Type, STP: Storage Period (Month), Myristic (C14:0), Palmitic (C16:0), palmitoleic (C16:1), Margaric (C17:0), Margoleic (C17:1), Stearic (C18:0), Oleic (C18:1), Linoleic (C18:2), Linolenic (C18:3), Arachidic (C20:0), Gadoleic (C20:0), Behenic (C22:0), Lignoceric (C24:0), Saturated Fatty Acids (SFA), Monounsaturated fatty acids (MUFA), Polyunsaturated fatty acids (PUFA).
MI: Olgunluk İndeksi, V: Çeşit, ST: Depolama Tipi, STP: Depolama Süresi (Ay), Miristik (C14:0), Palmitik (C16:0), Palmitoleik (C16:1), Margarik (C17:0), Margoleik (C17:1), Stearik (C18:0), Oleik (C18:1), Linoleik (C18:2), Linolenik (C18:3), Arakidik (C20:0), Gadoleik (C20:0), Behenik (C22:0), Lignoserik (C24:0), Doymuş Yağ Asitleri (SFA), Tekli Doymamış Yağ Asitleri (MUFA), Çoklu Doymamış Yağ Asitleri (PUFA).

Table 2. The composition of fatty acids (%) in Ayvalık (A) and Memecik (M) olive oils at different MI in daylight and dark, in the second harvest year during 15 months storage

Çizelge 2. İkinci hasat yılında 15 aylık depolama süresince, farklı MI değerlerinde, gün ışığında ve karanlıkta, Ayvalık (A) ve Memecik (M) zeytinyağlarındaki yağ asitlerinin kompozisyonları (%)

MI	V	ST	STP	C14:0	C16:0	C16:1	C17:0	C17:1	C18:0	C18:1	C18:2T	C18:2	18:3T	C18:3	C20:0	C20:1	C22:0	C24:0	SFA	MUFA	PUFA
1	A	DL	0	0.02	14.83±0.01	1.28	0.13	0.24	2.18	67.20±0.01	0.01	12.37±0.01	0.00	0.74	0.44	0.33	0.14	0.07	17.82	69.06±0.03	13.11
			5	0.02	16.37±0.01	1.21	0.13	0.23	2.18	66.24±0.01	0.02	11.89±0.01	0.00	0.70	0.44	0.33	0.14	0.07	19.36	68.01±0.04	12.60
			10	0.02	16.04±0.00	1.23	0.13	0.23	2.13	66.75±0.02	0.02	11.92±0.02	0.03	0.70	0.42	0.31	0.13	0.07	18.94	68.52±0.04	12.62
			15	0.02	15.06±0.02	1.19	0.13	0.23	2.16	67.18±0.02	0.02	12.23±0.02	0.03	0.74	0.44	0.33	0.13	0.08	18.02	68.94±0.05	12.97
1	A	D	0	0.02	14.83±0.01	1.28	0.13	0.24	2.18	67.20±0.03	0.01	12.37±0.03	0.00	0.74	0.44	0.33	0.14	0.07	17.82	69.06±0.04	13.11
			5	0.02	15.38±0.01	1.23	0.13	0.23	2.16	67.04±0.04	0.02	12.01±0.02	0.00	0.70	0.44	0.33	0.13	0.07	18.33	68.82±0.03	12.71
			10	0.02	15.84±0.02	1.19	0.13	0.23	2.17	67.11±0.02	0.01	11.87±0.01	0.04	0.69	0.43	0.32	0.13	0.07	18.79	68.85±0.03	12.55
			15	0.02	15.71±0.00	1.25	0.13	0.24	2.12	66.65±0.03	0.02	12.16±0.01	0.03	0.72	0.42	0.31	0.12	0.07	18.58	68.45±0.04	12.89
2	A	DL	0	0.02	15.19±0.02	1.32	0.13	0.23	2.13	66.22±0.01	0.02	12.96±0.02	0.00	0.76	0.45	0.34	0.15	0.08	18.14	68.11±0.04	13.72
			5	0.02	15.47±0.02	1.33	0.12	0.23	2.06	65.98±0.02	0.02	12.99±0.03	0.04	0.77	0.42	0.32	0.13	0.07	18.30	67.86±0.03	13.76
			10	0.02	15.26±0.01	1.24	0.12	0.22	2.13	66.65±0.03	0.02	12.71±0.03	0.02	0.71	0.45	0.34	0.15	0.08	18.21	68.44±0.04	13.42
			15	0.02	15.49±0.01	1.27	0.12	0.23	2.08	66.03±0.02	0.02	12.92±0.02	0.03	0.77	0.43	0.32	0.14	0.07	18.36	67.86±0.03	15.99
2	A	D	0	0.02	15.19±0.01	1.32	0.13	0.23	2.13	66.22±0.01	0.02	12.96±0.03	0.00	0.76	0.45	0.34	0.15	0.08	18.14	68.11±0.04	13.72
			5	0.03	15.42±0.03	1.33	0.12	0.24	2.06	66.05±0.03	0.02	12.96±0.01	0.03	0.77	0.42	0.32	0.13	0.07	18.26	67.93±0.03	13.73
			10	0.02	15.17±0.03	1.25	0.12	0.22	2.11	66.46±0.02	0.01	12.85±0.01	0.02	0.74	0.45	0.34	0.14	0.08	18.09	68.28±0.04	13.59
			15	0.02	15.39±0.02	1.31	0.12	0.24	2.07	66.09±0.01	0.02	12.96±0.02	0.03	0.77	0.42	0.32	0.14	0.07	18.24	67.95±0.03	15.98

MI: Maturity Index, V: Variety, ST: Storage Type, STP: Storage Period (Month), Myristic (C14:0), Palmitic (C16:0), palmitoleic (C16:1), Margaric (C17:0), Margoleic (C17:1), Stearic (C18:0), Oleic (C18:1), Linoleic (C18:2), Linolenic (C18:3), Arachidic (C20:0), Gadoleic (C20:0), Behenic (C22:0), Lignoceric (C24:0), Saturated Fatty Acids (SFA), Monounsaturated fatty acids (MUFA), Polyunsaturated fatty acids (PUFA).
MI: Olgunluk İndeksi, V: Çeşit, ST: Depolama Tipi, STP: Depolama Süresi (Ay), Miristik (C14:0), Palmitik (C16:0), Palmitoleik (C16:1), Margarik (C17:0), Margoleik (C17:1), Stearik (C18:0), Oleik (C18:1), Linoleik (C18:2), Linolenik (C18:3), Arakidik (C20:0), Gadoleik (C20:0), Behenik (C22:0), Lignoserik (C24:0), Doymuş Yağ Asitleri (SFA), Tekli Doymamış Yağ Asitleri (MUFA), Çoklu Doymamış Yağ Asitleri (PUFA).

Table 2. The composition of fatty acids (%) in Ayvalık (A) and Memecik (M) olive oils at different MI in daylight and dark, in the second harvest year during 15 months storage (continued)

Çizelge 2. İkinci hasat yılında 15 aylık depolama süresince, farklı MI değerlerinde, gün ışığında ve karanlıkta, Ayvalık (A) ve Memecik (M) zeytinyağlarındaki yağ asitlerinin kompozisyonları (%) (devamı)

MI	V	ST	STP	C14:0	C16:0	C16:1	C17:0	C17:1	C18:0	C18:1	C18:2T	C18:2	18:3T	C18:3	C20:0	C20:1	C22:0	C24:0	SFA	MUFA	PUFA
1	M	DL	0	0.03	15.36±0.00	1.29	0.04	0.07	2.21	65.63±0.01	0.02	13.40±0.01	0.00	0.94	0.45	0.32	0.14	0.08	18.31	67.32±0.03	14.34
			5	0.02	16.07±0.01	1.25	0.04	0.07	2.20	65.21±0.03	0.02	13.21±0.01	0.00	0.92	0.45	0.32	0.13	0.08	18.99	66.85±0.04	14.12
			10	0.03	15.77±0.02	1.25	0.04	0.06	2.14	65.70±0.02	0.02	13.66±0.01	0.00	0.92	0.45	0.32	0.13	0.08	18.63	67.33±0.04	14.58
			15	0.02	15.55±0.00	1.25	0.04	0.07	2.18	65.55±0.01	0.02	13.37±0.02	0.01	0.95	0.45	0.32	0.13	0.08	18.45	67.19±0.05	13.59
1	M	D	0	0.03	15.36±0.03	1.29	0.04	0.07	2.21	65.63±0.02	0.02	13.40±0.03	0.00	0.94	0.45	0.32	0.14	0.08	18.31	67.32±0.03	14.34
			5	0.02	15.75±0.01	1.24	0.04	0.07	2.22	65.39±0.02	0.02	13.10±0.02	0.00	0.90	0.46	0.32	0.14	0.08	18.71	67.17±0.04	14.00
			10	0.03	15.47±0.01	1.14	0.04	0.06	2.27	66.16±0.03	0.02	12.91±0.00	0.00	0.85	0.48	0.33	0.15	0.08	18.53	67.69±0.04	13.76
			15	0.02	15.57±0.02	1.24	0.04	0.07	2.16	65.54±0.01	0.02	13.38±0.01	0.01	0.94	0.45	0.32	0.13	0.08	18.45	67.16±0.04	13.70
2	M	DL	0	0.02	14.32±0.01	1.09	0.04	0.07	2.17	67.34±0.01	0.02	13.08±0.02	0.00	0.85	0.44	0.35	0.13	0.07	17.19	68.85±0.04	13.93
			5	0.02	14.25±0.02	1.11	0.04	0.07	2.10	67.27±0.01	0.03	13.28±0.03	0.01	0.88	0.41	0.32	0.12	0.06	17.00	68.77±0.03	14.16
			10	0.02	14.18±0.02	1.06	0.04	0.06	2.15	67.57±0.02	0.02	13.09±0.01	0.00	0.86	0.44	0.35	0.13	0.07	17.02	69.03±0.05	13.95
			15	0.02	13.97±0.02	1.06	0.04	0.06	2.16	67.48±0.02	0.02	13.28±0.01	0.01	0.88	0.43	0.33	0.13	0.07	16.82	68.93±0.04	14.16
2	M	D	0	0.02	14.32±0.03	1.09	0.04	0.07	2.17	67.34±0.02	0.02	13.08±0.00	0.00	0.85	0.44	0.35	0.13	0.07	17.19	68.85±0.03	13.93
			5	0.02	14.41±0.01	1.09	0.04	0.06	2.13	67.14±0.03	0.02	13.22±0.01	0.01	0.88	0.42	0.33	0.12	0.07	17.21	68.63±0.04	14.10
			10	0.02	14.22±0.00	1.04	0.04	0.06	2.16	67.70±0.03	0.01	12.94±0.01	0.00	0.81	0.44	0.34	0.13	0.07	17.08	69.15±0.04	13.76
			15	0.02	14.16±0.01	1.06	0.04	0.07	2.11	67.42±0.01	0.02	13.22±0.03	0.01	0.87	0.43	0.33	0.13	0.08	16.96	68.88±0.03	14.09

MI: Maturity Index, V: Variety, ST: Storage Type, STP: Storage Period (Month), Myristic (C14:0), Palmitic (C16:0), palmitoleic (C16:1), Margaric (C17:0), Margoleic (C17:1), Stearic (C18:0), Oleic (C18:1), Linoleic (C18:2), Linolenic (C18:3), Arachidic (C20:0), Gadoleic (C20:0), Behenic (C22:0), Lignoceric (C24:0), Saturated Fatty Acids (SFA), Monounsaturated fatty acids (MUFA), Polyunsaturated fatty acids (PUFA).

MI: Olgunluk İndeksi, V: Çeşit, ST: Depolama Tipi, STP: Depolama Süresi (Ay), Miristik (C14:0), Palmitik (C16:0), Palmitoleik (C16:1), Margarik (C17:0), Margoleik (C17:1), Stearik (C18:0), Oleik (C18:1), Linoleik (C18:2), Linolenik (C18:3), Arakidik (C20:0), Gadoleik (C20:0), Behenik (C22:0), Lignoserik (C24:0), Doymuş Yağ Asitleri (SFA), Tekli Doymamış Yağ Asitleri (MUFA), Çoklu Doymamış Yağ Asitleri (PUFA)

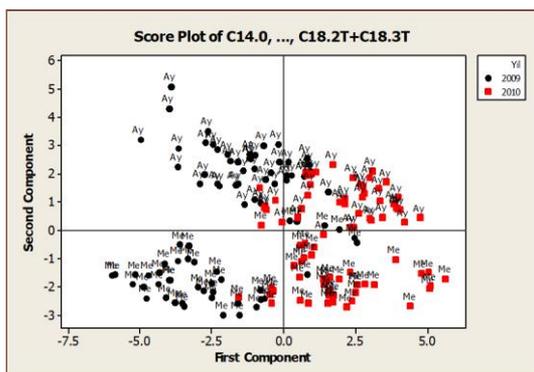


Figure 3. PCA score plot of Ayvalık (Ay) and Memecik (Me) olive oils fatty acid composition in the first and the second harvest years.

Şekil 3. Ayvalık (Ay) ve Memecik (Me) zeytinyağlarının birinci ve ikinci hasat yıllarındaki yağ asidi kompozisyonunun PCA skor çizelgesi

As illustrated in Figure 3, the PCA score plot of Ayvalık and Memecik oils in the initial and secondary harvest years is presented. According to the results of PCA, the score plot of the first (PC1) and second (PC2) principal component demonstrated that the samples were classified into two primary groups with respect to the harvest years. Furthermore, a successful clustering of the samples into two sub-groups was achieved based on their cultivars (Ayvalık and Memecik), which underscores the influence of both genetic factors and environmental conditions during fruit development on the observed outcomes.

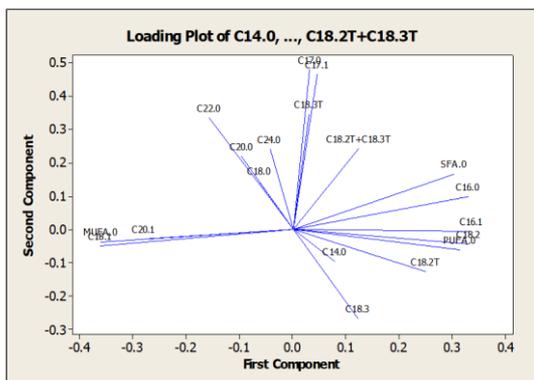


Figure 4. PCA loading plot of fatty acid composition of Ayvalık and Memecik olive oils.

Şekil 4. Ayvalık ve Memecik zeytinyağlarının yağ asidi kompozisyonunun PCA yükleme grafiği.

As illustrated in Figure 4, the PCA loading plot of the fatty acid composition of Ayvalık and Memecik olive oil is shown. The PCA results indicated that the variables C18:0, C20:0, C22:0, C24:0 and C18:1, C20:1, MUFA had a significant impact in the characterization of the olive oil samples obtained in

the first harvest years, Ayvalık and Memecik, respectively. Furthermore, the analysis of the olive oils revealed that they were predominantly characterized by the presence of certain fatty acids, including C16:0, C16:1, C17:0, C17:1, C18:3T, C18:2T+C18:3T, SFA, and C14:0, C18:2, C18:2T, C18:3, and PUFA, as obtained in the second harvest years of Ayvalık and Memecik, respectively.

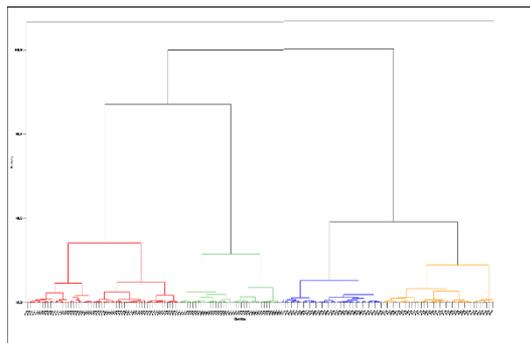


Figure 5. The HCA dendrogram of Ayvalık and Memecik olive oils at first and second maturation index in 2009 and 2010 harvest years.

Şekil 5. 2009 ve 2010 hasat yıllarında birinci ve ikinci olgunlaşma indeksindeki Ayvalık ve Memecik zeytinyağlarının HCA dendrogramı.

According to the HCA results the oils obtained from Ayvalık and Memecik olives are separated into four groups; A, B, C and D (Figure 5). The clustering was observed in Ayvalık ve Memecik varieties but the differences were not observed in clusters according to the MI. Ayvalık and Memecik olive oils showed differences according to years. Memecik olive oils were clustered at B group in the first harvest year and at C group in the second harvest year. Ayvalık olive oils were clustered at A group in the first harvest year and at D group in the second harvest year. There was no difference observed between the 1th and 2nd harvest. In our research, there was not a significant difference of fatty acid composition of olive oils with maturation. This can be caused by close MI. The MI values are near the each other.

Sterol and Erythrodiol+Uvaol Contents

The findings pertaining to the sterol and triterpenic dialcohol contents (in percent) of the olive oil samples are documented in Table 3 and Table 4. The results indicated that β -sitosterol, Δ 5-avenasterol and campesterol were the most predominant sterols. In addition, the presence of cholesterol, brassicasterol, 24-metilen cholesterol, campestanol, stigmasterol, Δ 7-campesterol, clerosterol, sitostanol, Δ 5-24-stigmastadienol, Δ 7-stigmastenol, Δ 7-avenasterol, eritrodiol, and uvaol was confirmed in all samples, albeit in lower concentrations. Memecik olive oil has higher levels of certain

nutrients, including brassicasterol, stigmasterol, and uvaol, compared to Ayvalık olive oil, which has higher levels of campesterol, $\Delta 5$ -avenasterol, and total sterol.

Sterol oxidation increases during extra virgin olive oil storage as a result of reactions with light, high temperatures, and oxygen; the degree of unsaturation determines this increase (El Bernoussi et al., 2020). Generally, an increasing tendency was observed along the ripeness in the values of $\Delta 5$ -avenasterol. β -sitosterol values of the oils decreased, while erythrodiol+uvaol, values increased during 15 months storage. During the storage period every result fell within the IOC's bounds (2022) aside from delta-7-stigmastenol and brassicasterol. The delta-7-stigmastenol value varied between 0.51 and 0.63%, varied between 0.51 and 0.94%, in the first and the second harvest year, respectively. For brassicasterol only in the first harvest year, it was determined to be 0.15% in the 15th month of storage. β -sitosterol level in olive oil decreased during storage period. Thanh et al. (2006) reported that olive oil's β -sitosterol level declined 16.5% after 6 months of storage at room temperature. Abu-Alruz et al. (2011) reported an increase in $\Delta 7$ -stigmastenol after 6 months of storage in different containers. Lukić et al. (2013) reported a decrease in stigmasterol, campesterol, $\Delta 5,24$ -stigmastadienol, and uvaol, and a significant increase in β -sitosterol, and in campestanol levels after 12 months of storage of extra virgin olive oils at different temperatures. Our study yielded similar results. Rey-Giménez et al. (2022) stated that the degree of olive maturity was important only for $\Delta 7$ -sterols, and the harvest year played an important role in correctly classifying 94.9% of the oils. According to studies, the total sterol loss in oils that are kept closed for the duration of storage is minimal at low temperatures (+4°C and -18°C). According to studies, EVOO is able to be kept at low temperatures for up to 36 months, as long as it stays within the legal bounds created by the present EU regulations that apply to the majority of compounds (Mousavi et al., 2021).

PCA score plots for the first (PC1) and second (PC2) principal components were used to analyze the sterol composition of the samples. The results of this analysis revealed that the samples could be classified into two main groups, based on their cultivar, Ayvalık and Memecik (Figure 6). The PCA analysis revealed that the sterol composition of oils extracted from different MI, harvest years, and storage conditions remained relatively constant and did not exhibit significant variation.

Figure 7 shows the PCA loading plot of sterol composition of Ayvalık and Memecik olive oil. The results of the PCA indicated that the following compounds were important for the description of the Memecik olive oil samples: β -sitosterol,

stigmasterol, cholesterol, clerosterol, brassicasterol, and eritrodiol+uvaol. In addition, Ayvalık olive oils were essentially characterized with campestanol, sitosterol, campestanol, $\Delta 7$ -avenasterol, $\Delta 5$ -avenasterol, total sterol, $\Delta 5$ -7 stigmastadienol and total β -sitosterol.

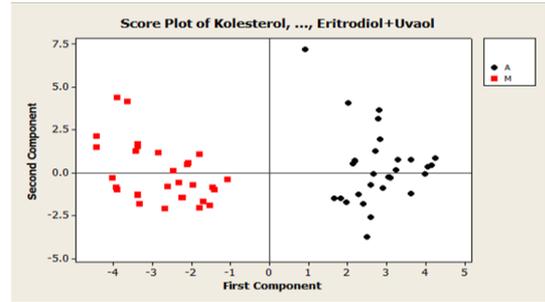


Figure 6. Score plot of PCA results of Ayvalık (A) and Memecik (M) olive oils based on the sterol composition data in daylight and dark storage conditions in 2009 and 2010 harvest years.

Şekil 6. 2009 ve 2010 hasat yıllarında gün ışığında ve karanlıkta depolama koşullarında Ayvalık (A) ve Memecik (M) zeytinyağlarının sterol kompozisyon verilerine göre PCA sonuçlarının puan grafiği.

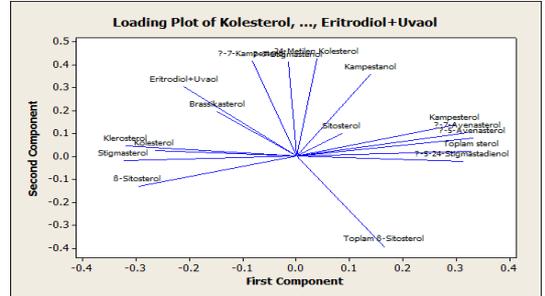


Figure 7. Loading plot of PCA based on the sterol composition results of Ayvalık and Memecik olive oils in 2009 and 2010 harvest years.

Şekil 7. 2009 ve 2010 hasat yıllarında Ayvalık ve Memecik zeytinyağlarının sterol kompozisyon sonuçlarına dayalı PCA yüklem grafiği.

As indicated by the results of the HCA, the oils obtained from the Ayvalık and Memecik olive oils were separated into two distinct groups, as illustrated in Figure 8. The clustering was observed in Ayvalık ve Memecik varieties but the differences were not observed in clusters according to the MI, harvest years and also storage conditions. This can be caused by close MI.

Table 3. Evaluation of Sterol Composition of Ayvalık (A) and Memecik (M) olive oils at different MI in daylight and dark, in the first harvest year during 15 months storage.

Çizelge 3. Ayvalık (A) ve Memecik (M) zeytinyağlarının farklı MI değerlerinde, gün ışığında ve karanlıkta, ilk hasat yılında 15 aylık depolama süresince sterol kompozisyonlarının değerlendirilmesi

MI	V	ST	STP	Cholesterol (%)	Brassica sterol (%)	24-Mehylene Cholesterol (%)	Campesterol (%)	Campestanol (%)	Stigmasterol (%)	Δ -7-Campesterol (%)	Clerosterol (%)	β -Sitosterol (%)	Sitosteranol (%)	Δ -5-Avenasterol (%)	Δ -5-24-Stigmastadienol (%)	Δ -7-Stigmasterol (%)	Δ -7-Avenasterol (%)	Total Sterol (mg kg ⁻¹)	Total β -Sitosterol*	Erythrodiol +Uvaol (%)
1	A	DL	0	0.15	0.02	0.01	3.47	0.06	0.54	0.06	0.92	85.57±0.05	0.40	6.80±0.01	0.98	0.25	0.65	2404±0.14	94.68±0.04	0.68
			5	0.17	0.06	0.11	3.53	0.06	0.56	0.08	0.95	85.91±0.04	0.45	6.27±0.00	0.97	0.31	0.55	2377±0.15	94.55±0.05	0.92
			10	0.18	0.04	0.10	3.45	0.05	0.56	0.09	0.95	85.93±0.03	0.43	6.21±0.01	1.02	0.39	0.59	2291±0.17	94.54±0.04	1.04
			15	0.14	0.01	0.10	3.45	0.10	0.57	0.08	0.81	84.55±0.05	0.69	7.38±0.01	1.03	0.42	0.65	2198±0.12	94.47±0.07	1.18
1	A	D	0	0.15	0.02	0.10	3.47	0.06	0.54	0.06	0.92	85.57±0.06	0.40	6.80±0.02	0.98	0.25	0.65	2404±0.17	94.68±0.05	0.68
			5	0.20	0.04	0.09	3.52	0.06	0.57	0.09	0.96	85.24±0.05	0.43	6.89±0.02	0.94	0.28	0.68	2260±0.18	94.46±0.07	0.79
			10	0.17	0.05	0.09	3.50	0.08	0.55	0.12	0.91	84.70±0.04	0.57	6.84±0.01	1.11	0.61	0.70	2345±0.25	94.13±0.08	1.31
2	A	DL	0	0.15	0.02	0.12	3.58	0.07	0.48	0.08	0.91	85.68±0.04	0.38	6.99±0.01	0.59	0.27	0.66	2333±0.18	94.55±0.10	0.58
			5	0.21	0.02	0.12	3.59	0.08	0.49	0.09	0.92	85.34±0.06	0.54	6.96±0.02	0.65	0.29	0.70	2340±0.19	94.40±0.08	0.66
			10	0.21	0.04	0.14	3.64	0.10	0.49	0.10	0.90	84.81±0.07	0.46	7.15±0.03	0.70	0.51	0.73	2396±0.24	94.04±0.09	0.99
			15	0.19	0.02	0.11	3.56	0.14	0.45	0.08	0.82	84.09±0.04	0.84	7.88±0.01	0.72	0.37	0.70	2348±0.13	94.36±0.07	0.95
2	A	D	0	0.15	0.02	0.12	3.58	0.07	0.48	0.08	0.91	85.68±0.04	0.38	6.99±0.00	0.59	0.27	0.66	2333±0.11	94.55±0.11	0.58
			5	0.21	0.02	0.13	3.60	0.09	0.50	0.08	0.92	84.84±0.03	0.56	7.20±0.00	0.72	0.35	0.77	2346±0.17	94.25±0.05	0.69
			10	0.22	0.02	0.11	3.60	0.10	0.49	0.10	0.86	84.70±0.05	0.58	7.14±0.01	0.78	0.63	0.66	2374±0.19	94.07±0.07	1.18
2	A	D	15	0.14	0.01	0.13	3.65	0.14	0.47	0.10	0.90	83.90±0.06	0.86	7.92±0.03	0.77	0.28	0.73	2315±0.14	94.34±0.08	1.22

MI: Maturity Index, V: Variety, ST: Storage Type, STP: Storage Period (Month).

MI: Olgunluk Endeksi, V: Çeşit, ST: Depolama Tipi, STP: Depolama Süresi (Ay).

Table 3. Evaluation of Sterol Composition of Ayvalık (A) and Memecik (M) olive oils at different MI in daylight and dark, in the first harvest year during 15 months storage (continued)

Çizelge 3. Ayvalık (A) ve Memecik (M) zeytinyağlarının farklı MI değerlerinde, gün ışığında ve karanlıkta, ilk hasat yılında 15 aylık depolama süresince sterol kompozisyonlarının değerlendirilmesi (devamı)

MI	V	ST	STP	Cholesterol (%)	Brassica sterol (%)	24-Mehylene Cholesterol (%)	Campesterol (%)	Campestanol (%)	Stigma stenol (%)	Δ -7-Campesterol (%)	Clero sterol (%)	β -Sito sterol (%)	Sito stanol (%)	Δ -5-Avena sterol (%)	Δ -5-24-Stigma stadienol (%)	Δ -7-Stigma stenol (%)	Δ -7-Avena sterol (%)	Total Sterol (mg kg ⁻¹)	Total β -Sitos terol*	Erytrodiol +Uvaol (%)
1	M	DL	0	0.31	0.05	0.09	3.08	0.05	1.79	0.08	1.08	84.22±0.05	0.32	3.28±0.01	0.23	0.27	0.31	1337±0.14	93.70±0.10	1.35
			5	0.25	0.03	0.10	3.26	0.06	1.92	0.12	1.17	88.96±0.05	0.43	2.93±0.00	0.20	0.30	0.25	1281±0.12	93.70±0.09	1.26
			10	0.34	0.04	0.12	3.27	0.12	1.89	0.14	1.22	88.05±0.05	0.38	3.42±0.02	0.26	0.37	0.35	1272±0.17	93.34±0.11	2.06
			15	0.25	0.08	0.13	3.24	0.17	1.83	0.13	1.17	87.46±0.04	0.61	3.65±0.02	0.36	0.32	0.31	1347±0.19	93.54±0.11	1.69
1	M	D	0	0.31	0.05	0.09	3.08	0.05	1.79	0.08	1.08	84.22±0.07	0.32	3.28±0.01	0.23	0.27	0.31	1337±0.15	93.70±0.13	1.35
			5	0.23	0.04	0.10	3.23	0.06	1.92	0.11	1.19	88.94±0.03	0.43	3.03±0.01	0.18	0.28	0.25	1270±0.14	93.77±0.10	1.29
			10	0.22	0.06	0.10	3.22	0.09	1.94	0.08	1.22	88.50±0.05	0.30	3.38±0.01	0.24	0.32	0.33	1330±0.20	93.64±0.14	1.87
			15	0.20	0.10	0.13	3.21	0.20	2.00	0.08	1.12	87.74±0.04	0.66	3.56±0.02	0.30	0.41	0.29	1273±0.18	93.38±0.15	1.78
2	M	DL	0	0.27	0.02	0.12	3.42	0.04	1.42	0.09	1.20	87.61±0.05	0.37	4.50±0.00	0.27	0.22	0.40	1578±0.11	94.00±0.10	1.06
			5	0.30	0.02	0.13	3.41	0.04	1.43	0.14	1.12	87.52±0.04	0.58	4.45±0.02	0.26	0.24	0.34	1608±0.14	93.95±0.08	1.07
			10	0.24	0.05	0.12	3.46	0.06	1.49	0.12	1.18	87.43±0.02	0.35	4.47±0.01	0.27	0.35	0.40	1634±0.12	93.71±0.12	1.46
			15	0.17	0.00	0.15	3.37	0.11	1.40	0.17	1.12	87.52±0.04	0.61	4.33±0.01	0.33	0.36	0.35	1479±0.17	93.91±0.13	1.49
2	M	D	0	0.27	0.02	0.12	3.42	0.04	1.42	0.09	1.20	87.61±0.06	0.37	4.55±0.02	0.27	0.22	0.40	1578±0.18	94.00±0.10	1.06
			5	0.29	0.04	0.11	3.38	0.05	1.45	0.10	1.14	87.86±0.05	0.46	4.18±0.00	0.24	0.25	0.42	1597±0.18	93.78±0.11	1.24
			10	0.24	0.06	0.12	3.46	0.08	1.49	0.14	1.20	87.31±0.04	0.36	4.43±0.03	0.25	0.45	0.39	1550±0.17	93.57±0.12	1.65
			15	0.18	0.00	0.11	3.40	0.11	1.40	0.12	1.06	87.04±0.04	0.84	4.64±0.01	0.45	0.25	0.38	1575±0.14	94.05±0.10	1.49

MI: Maturity Index, V: Variety, ST: Storage Type, STP: Storage Period (Month)

MI: Olgunluk Endeksi, V: Çeşit, ST: Depolama Tipi, STP: Depolama Süresi (Ay).

Table 4. Evaluation of Sterol Composition of Ayvalık (A) and Memecik (M) olive oils at different MI in daylight and dark, in the second harvest year during 15 months storage
Çizelge 4. İkinci hasat yılında 15 aylık depolama süresince, farklı MI değerlerinde, gün ışığında ve karanlıkta, Ayvalık (A) ve Memecik (M) zeytinyağlarının sterol kompozisyonunun değerlendirilmesi

MI	V	ST	STP	Chole sterol (%)	Brassica sterol (%)	24-Mehylene Chole sterol (%)	Campe sterol (%)	Campe stanol (%)	Stigma stenol (%)	Δ -7-Campe sterol (%)	Clero sterol (%)	β -Sito sterol (%)	Sito stanol (%)	Δ -5-Avena sterol (%)	Δ -5-24-Stigma stadienol (%)	Δ -7-Stigma stenol (%)	Δ -7-Avena sterol (%)	Total Sterol (mg kg ⁻¹)	Total β -Sito sterol	Erythrodiol +Uvaol (%)
1	A	DL	0	0.14	0.04	0.09	3.70	0.10	0.59	0.09	0.90	83.78±0.05	0.44	7.87±0.01	1.06	0.34	0.86	2170±0.14	94.06±0.09	1.30
			5	0.10	0.00	0.10	3.75	0.16	0.59	0.11	0.89	83.20±0.07	0.62	8.27±0.02	1.06	0.32	0.83	2434±0.18	94.04±0.10	1.16
			10	0.12	0.00	0.11	3.74	0.16	0.57	0.11	0.88	82.84±0.04	0.92	8.57±0.02	0.88	0.35	0.78	2416±0.15	94.01±0.07	0.78
			15	0.16	0.04	0.14	3.77	0.19	0.65	0.16	0.99	82.79±0.03	0.81	8.27±0.02	0.71	0.56	0.76	2293±0.14	93.57±0.07	1.02
1	A	D	0	0.14	0.04	0.09	3.70	0.10	0.59	0.09	0.90	83.78±0.05	0.44	7.87±0.00	1.06	0.34	0.86	2170±0.13	94.06±0.08	1.30
			5	0.10	0.00	0.12	3.70	0.12	0.65	0.12	0.96	83.39±0.05	0.65	8.13±0.00	0.88	0.38	0.79	2433±0.18	94.02±0.11	1.33
			10	0.14	0.00	0.11	3.82	0.16	0.57	0.12	0.91	82.46±0.06	1.07	8.54±0.03	0.98	0.34	0.76	2426±0.17	93.98±0.12	0.80
			15	0.14	0.07	0.14	3.74	0.11	0.58	0.12	0.94	83.41±0.07	0.60	7.89±0.01	0.92	0.47	0.86	2352±0.19	93.76±0.09	1.32
2	A	DL	0	0.10	0.01	0.10	3.72	0.12	0.51	0.08	0.85	84.57±0.06	0.35	7.59±0.02	0.96	0.27	0.76	2212±0.20	94.33±0.10	0.85
			5	0.17	0.00	0.14	3.65	0.13	0.58	0.13	0.96	83.59±0.05	0.85	7.77±0.01	0.90	0.38	0.73	2298±0.19	94.09±0.09	1.52
			10	0.11	0.00	0.12	3.67	0.17	0.60	0.16	0.95	83.60±0.05	0.72	7.85±0.01	1.01	0.29	0.75	2320±0.18	94.13±0.09	0.70
			15	0.14	0.02	0.18	3.74	0.16	0.62	0.18	0.94	83.68±0.06	0.60	7.85±0.01	0.59	0.56	0.73	2183±0.17	93.67±0.08	1.96
2	A	D	0	0.10	0.01	0.10	3.72	0.12	0.51	0.08	0.85	84.57±0.07	0.35	7.60±0.02	0.96	0.27	0.76	2212±0.19	94.33±0.07	0.85
			5	0.22	0.00	0.16	3.72	0.24	0.59	0.17	0.99	82.93±0.08	1.01	7.98±0.00	0.89	0.46	0.73	2344±0.17	93.80±0.08	1.62
			10	0.13	0.00	0.13	3.74	0.15	0.51	0.09	0.89	83.62±0.07	0.67	8.03±0.00	0.98	0.30	0.75	2432±0.18	94.20±0.10	0.84
			15	0.20	0.15	0.24	3.68	0.20	0.57	0.22	1.04	83.50±0.05	0.74	7.34±0.01	0.65	0.71	0.75	2248±0.19	93.27±0.11	1.86

MI: Maturity Index, V: Variety, ST: Storage Type, STP: Storage Period (Month)
MI: Olgunluk Endeksi, V: Çeşit, ST: Depolama Türü, STP: Depolama Süresi (Ay)

Table 4. Evaluation of Sterol Composition of Ayvalık (A) and Memecik (M) olive oils at different MI in daylight and dark, in the second harvest year during 15 months storage (continued)

Çizelge 4. İkinci hasat yılında 15 aylık depolama süresince, farklı MI değerlerinde, gün ışığında ve karanlıkta, Ayvalık (A) ve Memecik (M) zeytinyağlarının sterol kompozisyonunun değerlendirilmesi (devamı)

MI	V	ST	STP	Chole sterol (%)	Brassica sterol (%)	24-Mehylene Chole sterol (%)	Campe sterol (%)	Campe stanol (%)	Stigma stenol (%)	Δ -7-Campe sterol (%)	Clero sterol (%)	β -Sito sterol (%)	Sito stanol (%)	Δ -5-Avena sterol (%)	Δ -5-24-Stigma stadienol (%)	Δ -7-Stigma stenol (%)	Δ -7-Avena sterol (%)	Total Sterol (mg kg ⁻¹)	Total β -Sito sterol*	Erythrodiol +Uvaol (%)
1	M	DL	0	0.23	0.07	0.06	3.32	0.04	1.36	0.11	1.20	89.54±007	0.39	2.66±0.01	0.45	0.28	0.27	1453±0.14	94.26±007	1.54
			5	0.14	0.01	0.11	3.21	0.09	1.32	0.13	1.20	88.36±009	0.86	3.43±0.02	0.50	0.33	0.28	1525±0.12	94.37±008	1.48
			10	0.15	0.01	0.07	3.24	0.14	1.35	0.14	1.12	87.91±005	1.29	3.57±0.00	0.44	0.28	0.28	1480±0.17	94.34±005	1.24
			15	0.22	0.06	0.15	3.32	0.07	1.36	0.13	1.21	88.98±005	0.31	2.94±0.01	0.40	0.51	0.33	1472±0.12	93.85±005	2.02
1	M	D	0	0.23	0.07	0.06	3.32	0.04	1.36	0.11	1.20	89.54±007	0.39	2.66±0.02	0.45	0.28	0.27	1453±0.17	94.26±006	1.54
			5	0.13	0.00	0.09	3.23	0.10	1.33	0.12	1.14	88.00±006	1.13	3.57±0.00	0.48	0.36	0.30	1565±0.18	94.34±005	1.35
			10	0.17	0.00	0.06	3.35	0.08	1.34	0.14	1.15	88.09±004	0.75	3.89±0.01	0.36	0.29	0.33	1474±0.16	94.24±007	1.00
			15	0.27	0.10	0.14	3.38	0.04	1.40	0.14	1.26	89.04±005	0.31	2.63±0.02	0.35	0.59	0.34	1456±0.15	93.59±005	2.35
2	M	DL	0	0.23	0.07	0.06	3.32	0.03	1.35	0.10	1.10	88.62±008	0.61	3.56±0.01	0.42	0.23	0.32	1358±0.17	94.30±005	1.45
			5	0.28	0.00	0.08	3.26	0.11	1.39	0.14	1.13	86.52±009	0.65	5.00±0.00	0.46	0.57	0.40	1387±0.18	93.77±007	1.40
			10	0.25	0.00	0.07	3.18	0.08	1.33	0.12	1.08	87.67±007	0.77	4.49±0.02	0.40	0.22	0.34	1472±0.15	94.41±008	1.09
			15	0.24	0.09	0.17	3.32	0.11	1.37	0.20	1.25	87.84±005	0.56	3.46±0.02	0.23	0.79	0.35	1314±0.14	93.34±009	1.88
2	M	D	0	0.23	0.07	0.06	3.32	0.03	1.35	0.10	1.10	88.62±004	0.61	3.56±0.00	0.42	0.23	0.32	1358±0.19	94.30±011	1.45
			5	0.26	0.00	0.10	3.31	0.10	1.40	0.11	1.16	87.02±004	0.63	4.39±0.03	0.45	0.62	0.45	1438±0.16	93.63±007	1.34
			10	0.21	0.00	0.08	3.23	0.07	1.34	0.12	1.08	87.52±007	1.02	4.37±0.01	0.40	0.21	0.34	1423±0.14	94.39±009	1.12
			15	0.27	0.06	0.13	3.25	0.13	1.36	0.20	1.11	87.98±008	0.47	3.43±0.02	0.25	0.94	0.42	1289±0.17	93.23±007	1.90

MI: Maturity Index, V: Variety, ST: Storage Type, STP: Storage Period (Month)

MI: Olgunluk Endeksi, V: Çeşit, ST: Depolama Türü, STP: Depolama Süresi (Ay)

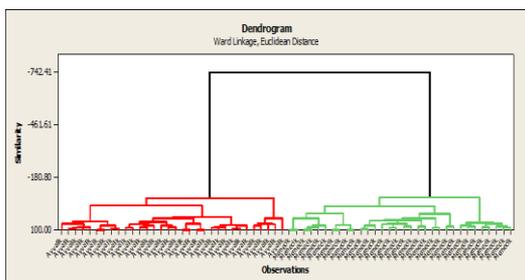


Figure 8. The dendrogram on HCA results of Ayvalık and Memecik olive oils in daylight and dark conditions at 1th and 2nd MI in 2009 and 2010 harvest years.

Şekil 8. 2009 ve 2010 hasat yıllarında 1. ve 2. MI'da gün ışığı ve karanlık koşullarında Ayvalık ve Memecik zeytinyağlarının HCA sonuçlarına ilişkin dendrogram.

Conclusion

Many variables influence olive oil composition and quality. These include ripening and storage of olives, as well as agricultural practices, raw material quality, harvest time, fruit storage conditions, and oil extraction technology.

In the study, it was determined that Memecik olive oil had higher oleic acid (C18:1) (71-72.7%) and MUFA content than Ayvalık olive oil in terms of fatty acid composition. High oleic acid is advantageous for cardiovascular health and is more resistant to oxidation. A comparative analysis revealed that Ayvalık olive oil exhibited a higher content of SFA and PUFA compared to Memecik olive oil. The palmitic acid (C16:0) and linoleic acid (C18:2) ratios are higher than those observed in Memecik. The presence of high levels of SFA has been demonstrated to impart heat resistance and shelf life stability.

In regard to the sterol and triterpenic components, a higher content of β -sitosterol, stigmasterol, brassicasterol, and erythrodiol+uvaol was observed in Memecik olive oil compared to Ayvalık olive oil. As is widely recognized, β -sitosterol, a phytosterol, has been demonstrated to reduce cholesterol absorption. The amount of erythrodiol+uvaol increased during storage (1.35-2.35%), which contributed to the antioxidant capacity. A comparative analysis of the olive oils from Ayvalık and Memecik revealed that Ayvalık olive oil exhibited higher concentrations of campestanol, Δ 5-avenasterol, and total sterol compared to Memecik olive oil. Notably, Δ 5-avenasterol, a sterol known for its role in enhancing oxidative stability, was found to be a distinguishing component in the Ayvalık olive oil. The total sterol content (2.404-2.198 mg kg⁻¹) is higher than that of Memecik (1.337-1.579 mg kg⁻¹). With respect to storage stability, both varieties satisfied the IOC criteria over a 15-month storage

period. Memecik olive oil demonstrates enhanced resistance to oxidation, attributable to its elevated MUFA content, Linoleic acid loss is reduced (and tends to be protected by antioxidants). Ayvalık olive oil sterol oxidation, particularly the increase in Δ 7-stigmasterol, is more pronounced, yet total sterol loss remains limited.

PCA and HCA analyses were performed to differentiate between the Memecik and Ayvalık varieties. These analyses revealed clear distinctions in the fatty acid and sterol profiles of the two varieties. Memecik was characterized by the presence of β -sitosterol and erythrodiol+uvaol, while Ayvalık was distinguished by the presence of campestanol and Δ 5-avenasterol. The two varieties were grouped in different clusters according to harvest year, and the effect of maturity index was found to be limited.

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