

## ARAŞTIRMA MAKALESİ

## RESEARCH ARTICLE

**Determination of Certain Physicochemical Properties of Olive Oils Under Different Storage Conditions\***

Zeytinyağlarının Farklı Depolama Koşulları Altındaki Bazı Fizikokimyasal Özelliklerinin Belirlenmesi

Damla GÜROCAK <sup>1</sup>, Cihangir SAĞLAM<sup>2\*</sup>, Yahya Tuncay TUNA<sup>3</sup>

**Abstract**

Olive oil is a widely consumed vegetable oil known for its health-promoting properties. Unlike most other vegetable oils, it is obtained directly from the fruit and produced entirely through physical processes without chemical treatment, allowing it to be consumed in its natural form while preserving its vitamins, essential fatty acids, and other bioactive compounds. Due to its high nutritional value and antioxidant content, olive oil is suitable for direct consumption; however, maintaining these properties depends largely on appropriate storage conditions and packaging. Nevertheless, insufficient awareness of proper storage practices may lead to quality deterioration, potentially reducing its health benefits. The aim of this study is to determine the effect of storing olive oil, which has a shelf life of two years, under different storage conditions and in different packaging materials for a period of 10 months on quality parameters. In the study, olive oil obtained from Ayvalık variety olives was stored for 10 months in 5 different materials: plastic bottles, amber-colored plastic bottles, glass bottles, dark-colored glass bottles and tin cans, in a bright and dark environment in a laboratory environment, in a way to be exposed to direct sunlight. Free fatty acidity and peroxide values were measured periodically (1 month). Acidity and peroxide determination of oil samples were made in laboratory environment. As a result, although the peroxide value remained below 20 meq O<sub>2</sub> kg<sup>-1</sup> in both environments, depending on the waiting time, the free fatty acidity value changed significantly. As the waiting time increased, it was observed that the free fatty acidity of olive oil stored in a dark plastic bottle, especially in a bright environment, reached the criterion of natural olive oil ( $\leq 0.8$ ) in the 2nd measurement.

**Keywords:** Storage duration, Light exposure, Shelf-life, Free fatty acidity, Peroxide value, Olive oil

<sup>1</sup>Damla Gürocak, Kandıra Ziraat Odası, Kocaeli, Türkiye. E-mail: [gurocakdamla@gmail.com](mailto:gurocakdamla@gmail.com)  ORCID: 0000-0001-5168-2222

<sup>2</sup>Sorumlu Yazar/Corresponding Author: Cihangir Sağlam, Tekirdağ Namık Kemal University, Faculty of Agriculture, Department of Biosystems Engineering, Tekirdağ, Türkiye. E-mail: [csaglamr@nku.edu.tr](mailto:csaglamr@nku.edu.tr)  ORCID: 0000-0001-8354-6540

<sup>3</sup>Yahya Tuncay Tuna, Tekirdağ Namık Kemal University, Faculty of Agriculture, Department of Animal Science, Tekirdağ, Türkiye. E-mail: [yttuna@nku.edu.tr](mailto:yttuna@nku.edu.tr)  ORCID: 0000-0002-4074-2282

Atıf: Gürocak, D., Sağlam, C., Tuna, Y. T. (2026). Zeytinyağlarının farklı depolama koşulları altındaki bazı fizikokimyasal özelliklerinin belirlenmesi. *Tekirdağ Ziraat Fakültesi Dergisi*, 23(4): 1482-1493.

Citation: Gürocak, D., Sağlam, C., Tuna, Y. T. (2026). Determination of certain physicochemical properties of olive oils under different storage conditions. *Journal of Tekirdag Agricultural Faculty*, 23(4): 1482-1493.

\*This study was summarized from the Damla GÜROCAK MSc thesis.

©Bu çalışma Tekirdağ Namık Kemal Üniversitesi tarafından Creative Commons Lisansı (<https://creativecommons.org/licenses/by-nc/4.0/>) kapsamında yayınlanmıştır. Tekirdağ 2026

## Öz

Zeytinyağı, sağlığı destekleyici özellikleriyle bilinen ve yaygın olarak tüketilen bir bitkisel yağdır. Çoğu diğer bitkisel yağdan farklı olarak, doğrudan meyveden elde edilmekte ve kimyasal işlem uygulanmadan tamamen fiziksel süreçlerle üretilmektedir; bu sayede vitaminlerini, esansiyel yağ asitlerini ve diğer biyoaktif bileşenlerini koruyarak doğal formunda tüketilebilmektedir. Yüksek besin değeri ve antioksidan içeriği nedeniyle doğrudan tüketime uygun olan zeytinyağının bu özelliklerini koruyabilmesi büyük ölçüde uygun depolama koşulları ve ambalajlamaya bağlıdır. Ancak, uygun depolama uygulamalarına ilişkin farkındalığın yetersiz olması kalite bozulmasına yol açarak sağlık üzerindeki olumlu etkilerini azaltabilmektedir. Bu çalışmanın amacı, raf ömrü iki yıl olan zeytinyağının farklı depolama koşulları ve farklı ambalaj materyallerinde 10 ay süreyle depolanmasının kalite parametreleri üzerine etkisini belirlemektir. Çalışmada, Ayvalık çeşidi zeytinlerden elde edilen zeytinyağı; plastik şişe, kehribar renkli plastik şişe, cam şişe, koyu renkli cam şişe ve teneke kutu olmak üzere 5 farklı materyalde, laboratuvar ortamında aydınlık ve karanlık koşullarda ve doğrudan güneş ışığına maruz kalacak şekilde 10 ay süreyle depolanmıştır. Serbest yağ asiditesi ve peroksit değerleri periyodik olarak (1 ay) ölçülmüştür. Yağ örneklerinin asitlik ve peroksit tayinleri laboratuvar ortamında gerçekleştirilmiştir. Sonuç olarak, her iki ortamda da peroksit değeri  $20 \text{ meq O}_2 \text{ kg}^{-1}$ 'in altında kalmasına rağmen, bekleme süresine bağlı olarak serbest yağ asitliği değerinde önemli değişimler meydana gelmiştir. Bekleme süresi arttıkça, özellikle aydınlık ortamda koyu renkli plastik şişede depolanan zeytinyağının serbest yağ asitliğinin ikinci ölçümde doğal zeytinyağı kriteri olan ( $\leq 0,8$ ) değerine ulaştığı gözlenmiştir.

**Anahtar Kelimeler:** Depolama süresi, Işık maruziyeti, Raf ömrü, Serbest yağ asiditesi, Peroksit değeri, Zeytinyağı

## 1. Introduction

The olive tree (*Olea europaea*) is classified in botanical systematics as belonging to the family *Oleaceae*, genus *Olea*, species *Olea europaea*, subspecies *Olea europaea sativa*. However, the genus *Olea* also includes approximately 20 species that grow in tropical and subtropical climatic conditions (Kayahan and Tekin, 2006). The tree can reach heights of 15- 20 m. Its fruits are initially green and ripen by turning purple during October-November. The olive tree generally has a long lifespan of 300-400 years; the existence of specimens exceeding 2000 years indicate remarkable drought resistance. (Kaplan and Arihan, 2012). For this reason, the olive tree has been referred to in mythology and botany as the “*immortal tree*”.

Olive oil is obtained by pressing the fruit of the olive (oil-bearing olives) and is the only vegetable oil that can be produced naturally through purely physical methods. Since it is produced without exposure to any chemical processing, it retains its vitamins, essential fatty acids, and other nutritional components during consumption (Tunanioğlu et al., 2003). Olive oil is a vegetable oil widely believed to promote health and is therefore frequently incorporated into daily dietary practices. In ancient Rome, it was considered the healthiest of all oils; traditions included bathing kings and emperors in oil and washing the deceased with it. Olive oil has also been known to be used in the treatment of wounds and inflammations (Jackson, 1999; Kaplan, 2025). The most distinguishing feature of olive oil compared to other vegetable oils is that it is derived directly from fruit and can be obtained exclusively through physical processes without undergoing any chemical treatment, making it suitable for natural consumption (Kara et al., 2011).

The olive is considered to originate from the eastern Mediterranean Basin. Turkey, geographically, partially encompasses this basin and possesses a rich source of olive biodiversity. Olive cultivation in Turkey is carried out in the Aegean, Marmara, Mediterranean, Southeastern Anatolia, and Black Sea regions (Nurengin et al., 2023). Although Türkiye is recognized as one of the native homelands of the olive tree, it has not attained the position it deserves in the olive and olive oil sector. The primary reasons for this situation include insufficient attention to proper agricultural techniques in cultivation and the inadequate integration of technological advancements, particularly during the processing of olives into oil (Kayahan and Tekin, 2006).

According to 2021 data from the International Olive Council (IOC), total global olive oil production amounted to 3.01 million tons. Of this total, 46.10% was produced by Spain, 9.10% by Italy, 9.10% by Greece, 7% by Türkiye, and 3.30% by Portugal. With an average annual production exceeding 210,000 tons, Türkiye ranks fourth among olive oil-producing countries worldwide (Anonim, 2021).

The production of olive oil generally involves three main stages: harvesting, pressing, and separation. This fundamental process has remained largely consistent throughout history. After the olives are crushed and converted into paste, the material undergoes pressing, and the extracted oil is subsequently collected in storage tanks.

One of the most significant technological advancements in olive oil production was the development of a circular crushing basin equipped with a rotating stone driven by its own weight. Initially powered by animal labor, this system later utilized water and wind energy, and today operates with mechanical power (Aydinoğlu, 2009). In modern mechanized systems, olives delivered to processing facilities first undergo preliminary preparation procedures. The purpose of these procedures is to remove leaves, soil, stones, and other foreign materials, thereby preparing the olives for the main processing stages. The objective of the crushing and malaxation processes is to release the oil contained within the fruit. While this operation was traditionally performed using stone mills, in modern continuous systems, stone mills have been replaced by metal crushers.

Quality in olive oil extends from olive cultivation to harvesting, and from post-harvest processing methods to storage and preservation conditions. Even the maintenance of the olive tree, including fertilization and disease and pest control, plays a significant role in determining olive oil quality. Proper harvesting methods carried out at the appropriate time are among the essential conditions for obtaining high-quality olive oil. Conversely, improper handling and processing of olives after harvest prevent the achievement of the desired quality. Therefore, quality in olive oil is established and preserved throughout every stage of production.

Factors such as olive cultivar, characteristics of the olive tree, soil structure, climatic conditions, and pest presence directly influence olive oil quality from the outset. Subsequently, harvesting methods, harvest timing, processing techniques, the type of machinery and equipment used, as well as storage and packaging conditions,

are all critical determinants of quality (Öztürk et al., 2014).

Particularly in olive oils stored in a ready-to-consume form, structural deterioration may occur over time due to sediment content, the type of storage container, environmental conditions, and duration of storage. These changes manifest as noticeable alterations in taste, aroma, and appearance. The physical properties of packaging materials, along with permeability and interactions between the olive oil and the packaging material, directly affect both the safety and quality of the oil. Equipment used for storage must be chemically inert, non-reactive with the oil, protective against light and air exposure, and maintained under controlled temperature conditions. Furthermore, to preserve the defining characteristics of olive oil, bottling should be carried out under a nitrogen atmosphere (Keçeli, 2008).

### ***1.1. Aim and scope of the study***

Olives are considerably more sensitive than oilseeds; therefore, to obtain high-quality edible olive oil, preserve its economic value, and ensure maximum market potential, olives must be processed into oil immediately after harvest. However, challenges encountered during harvesting, the necessity of completing harvest within the limited four-month period between November and March, and congestion in processing facilities make proper preservation of olives essential.

Due to their susceptibility to mechanical damage and high moisture content, olives are highly prone to enzymatic deterioration. Molds, yeasts, bacteria, and their spores present on the olive surface can rapidly proliferate, causing lipid degradation and an increase in free fatty acidity. Consequently, olives must be preserved using storage methods distinct from those applied to oilseeds.

Furthermore, even when olives are organically cultivated, obtaining organic certification for olive oil is difficult, as continuous processing systems may lead to mixing with other producers' oils. By identifying the most appropriate storage conditions, this study aims to provide organic producers with the opportunity to obtain olive oil at different times while maintaining quality and certification standards.

The scope of this study includes evaluating the suitability and economic feasibility of alternative storage methods at both regional and national levels. Determining the most effective preservation technique is expected to offer a practical solution to challenges faced by producers and processing enterprises in the olive oil sector, while also enhancing competitiveness within the rapidly expanding organic agriculture market.

Through this research, it is anticipated that the optimal storage method among different preservation approaches will be identified, enabling the production of high-quality olive oil or olive oil with minimal quality loss throughout all seasons.

## **2. Materials and Methods**

### ***2.1. Materials***

The primary material of this study consisted of olive oil obtained from the Ayvalık cultivar olives grown during the 2020-2021 harvest season in Keremköy, Ayvalık district of Balıkesir, Türkiye.

In the experiment, olive oil samples were stored under ten different storage conditions, comprising five different packaging materials kept in both light and dark environments. Over a storage period of ten months, selected quality parameters and physicochemical properties were analyzed. The storage materials were coded as follows: transparent plastic bottle (Y1), amber-colored plastic bottle (Y2), transparent glass bottle (Y3), colored glass bottle (Y4), and aluminum tin container (manufactured from soft steel and coated with tin-plated thin sheet metal) (Y5).

The supplementary materials consisted of an olive oil acidity determination kit and the analytical reagents necessary for conducting peroxide value measurements.

#### ***2.1.1. Characteristics of the Ayvalık olive cultivar used in the study***

The Ayvalık oil olive is extensively cultivated in Çanakkale province and its surrounding areas, where it constitutes a significant source of livelihood for local producers. High-quality olive oil is produced from the Ayvalık cultivar, with climatic factors playing a substantial role in enhancing its quality (Kaleci, 2010).

The Ayvalık olive accounts for approximately 25% of olive production in the Aegean Region. A significant

portion of the olive oil produced in Ayvalık is classified as extra virgin olive oil. In terms of chemical and sensory properties, its oil ranks among the highest quality and is predominantly utilized for oil production in the region. Under proper cultivation and maintenance conditions, the tree exhibits vigorous growth. The fruit is of medium size and shows moderate periodicity (alternate bearing tendency). It is a productive cultivar suitable for mechanical harvesting and is partially resistant to cold conditions.

### **2.1.2. Experimental storage containers**

In this study, olive oil samples obtained from practically stored batches were transferred into storage containers, each with a volume of 200 mL. The containers consisted of transparent PET bottles, amber-colored PET bottles, clear glass bottles, dark-colored glass bottles, and tin containers. The samples were subsequently analyzed for free fatty acidity and peroxide value to evaluate quality changes under different storage conditions.

### **2.1.3. Additional materials used in the study**

For the determination of free fatty acidity, an alcohol-ether solvent mixture and a phenolphthalein indicator solution prepared in alkaline medium were used. The analytical equipment included an analytical balance, a 250 mL Erlenmeyer flask, glass pipettes, a 100 mL graduated cylinder, an automatic pipette filler, and a 25 mL burette.

For peroxide value analysis, chloroform, glacial acetic acid, distilled water, potassium iodide, starch indicator solution, and a 0.002 N sodium thiosulfate standard titration solution were employed, along with standard laboratory glassware and equipment.

## **2.2. Methods**

### **2.2.1. Experimental design**

The experiments were conducted at the Biosystems Engineering Laboratory of the Faculty of Agriculture, Tekirdağ Namık Kemal University, during the 2020-2021 period. Olive oil samples were stored in 200 mL containers under ten different storage conditions, consisting of light and dark environments, with three replications per treatment. The samples were preserved for ten months and periodically analyzed at one-month intervals for free fatty acidity and peroxide value.

The study was carried out according to a completely randomized experimental design based on a  $5 \times 2 \times 10$  factorial design with three replications. The obtained data were subjected to analysis of variance (ANOVA) using the JMP statistical software package. Differences identified through variance analysis were further evaluated using Tukey's multiple comparison test.

### **2.2.2. Analytical methods**

#### **2.2.2.1. Determination of free fatty acidity values**

Free fatty acidity refers to the fatty acids present in the oil that are not bound to triglycerides and exist in a free state. The total amount of free fatty acids in oils is expressed either as a percentage of oleic acid or as the milligrams of potassium hydroxide (KOH) required to neutralize 1 gram of oil (Kıvrak, 2015).

The principle of the method is based on the titration of free fatty acids, dissolved in an alcohol- ether mixture, with a standardized alkaline solution in the presence of phenolphthalein as an indicator. The result is calculated based on the volume of standardized alkali solution consumed during titration.

Free fatty acidity values in the experimental samples were determined by titration with an alcohol-ether solvent mixture and phenolphthalein-containing alkaline solution, in accordance with TS 894 "Methods of Analysis for Edible Vegetable Oils," conducted in the Biosystems Engineering Laboratory.

A 10 g sample of olive oil was accurately weighed into a 250 mL Erlenmeyer flask. Subsequently, 30 mL of an alcohol-ether mixture was added to dissolve the oil completely. The solution was titrated with standardized potassium hydroxide solution containing phenolphthalein indicator until a persistent pale pink color was observed. The volume of alkali solution consumed was recorded and used for calculation of free fatty acids according to Eq. 1.

$$\% \text{Free Fatty Acids (as Oleic Acid)} = \left( \frac{V}{m} \right) \times 2.8 \quad (\text{Eq. 1}).$$

where V is the volume (mL) of 0.1 N ethanolic potassium hydroxide solution consumed during titration, and m is the mass (g) of the sample.

### 2.2.2.2. Determination of peroxide value

Peroxide value represents the amount of active oxygen present in oils and serves as an indicator of the degree of oxidative deterioration. Higher peroxide values indicate increased lipid oxidation and quality degradation (Kıvrak, 2015).

The peroxide value was determined based on the principle that peroxide oxygen present in the oil oxidizes potassium iodide, releasing free iodine, which is subsequently titrated with sodium thiosulfate.

A 2 g sample was weighed with a precision of 0.001 g, and 10 mL of chloroform was added to dissolve the oil. Subsequently, 15 mL of acetic acid and 1 mL of potassium iodide solution were added, and the mixture was shaken for 1 minute. The solution was then kept in the dark for 5 minutes. After this period, 75 mL of distilled water and 1 mL of starch indicator solution were added.

If the observed peroxide value was less than 12.5 meq O<sub>2</sub> kg<sup>-1</sup>, titration was carried out using 0.002 N sodium thiosulfate solution. If the peroxide value was 12.5 meq O<sub>2</sub> kg<sup>-1</sup> or higher, 0.01 N sodium thiosulfate solution was used for titration.

The peroxide value was calculated according to equation 2.

$$\text{Peroxide Value (meq O}_2\text{ kg}^{-1}) = \frac{(S-B) \times N \times 1000}{M} \quad (\text{Eq. 2}).$$

where S is the volume (mL) of sodium thiosulfate solution consumed during sample titration, B is the volume (mL) consumed in the blank titration, N is the normality of the sodium thiosulfate solution, and M is the mass (g) of the sample. The peroxide value is expressed as milliequivalents of active oxygen per kilogram of oil (meq O<sub>2</sub> kg<sup>-1</sup>).

## 3. Results and Discussion

Olives harvested on 29 November 2020 were processed into olive oil immediately after harvest, without any storage period. Free fatty acidity and peroxide value analyses were performed on 4 December 2020, and the obtained results are presented in the *Table 1*.

**Table 1. Initial Measurement Results**

| Measurement         | Free Fatty Acidity (%) | Peroxide Value (meq O <sub>2</sub> kg <sup>-1</sup> ) |
|---------------------|------------------------|-------------------------------------------------------|
| Initial Measurement | 0.5                    | 6.4                                                   |

After the initial measurement, the olive oil samples were transferred into five different container types, each with three replications. The containers were filled in a manner that prevented air exposure and were stored under two environmental conditions: a light environment exposed to direct sunlight and a dark environment protected from light.

Free fatty acidity and peroxide value analyses were conducted at 30-day intervals, resulting in a total of ten measurement periods. The results obtained from these analyses are presented below.

### 3.1. Statistical analysis

The experimental data were analyzed using the JMP statistical software package (SAS Institute Inc., 1989). The study was conducted according to a completely randomized design in a 5 × 2 × 10 factorial design with three replications. The data were subjected to analysis of variance (ANOVA) (*Table 2*), and treatment means were compared using Tukey's Honestly Significant Difference (HSD) test, developed by John W. Tukey (*Table 3*). Statistical differences were interpreted based on the test results, and the corresponding tables were generated accordingly.

**Table 2. Analysis of Variance for Free Fatty Acidity Values**

| Source of Variation       | Degrees of Freedom | Sum of Squares | Mean Square | F Value | P Value |
|---------------------------|--------------------|----------------|-------------|---------|---------|
| Time                      | 9                  | 8.684000       | 0.964888    | 4.31    | 0.001*  |
| Condition                 | 1                  | 13.483200      | 13.483200   | 60.25   | 0.001*  |
| Method                    | 4                  | 2.887333       | 0.72183325  | 3.22    | 0.0136* |
| Time x Condition          | 9                  | 2.046133       | 0.22734811  | 1.01    | 0.4284  |
| Time x Method             | 36                 | 7.578667       | 0.21051853  | 0.94    | 0.5701  |
| Condition x Method        | 4                  | 2.973467       | 0.74336675  | 3.32    | 0.0116* |
| Time x Condition x Method | 36                 | 7.593867       | 0.21094075  | 0.94    | 0.5670  |

\*Indicates statistical significance at the  $p < 0.05$  level.

**Table 3. Tukey's HSD Multiple Comparison Test for Free Fatty Acidity**

| Condition | Time | Y1                  | Y2                  | Y3                   | Y4                  | Y5                  | Mean                |
|-----------|------|---------------------|---------------------|----------------------|---------------------|---------------------|---------------------|
| LIGHT     | 1    | 0.6 <sup>7</sup>    | 0.6 <sup>7</sup>    | 0.6 <sup>7</sup>     | 0.6 <sup>7</sup>    | 0.6 <sup>7</sup>    | 0.60 <sup>4E</sup>  |
|           | 2    | 0.7 <sup>7</sup>    | 0.8 <sup>7</sup>    | 0.7 <sup>7</sup>     | 0.8 <sup>7</sup>    | 0.8 <sup>7</sup>    | 0.76 <sup>4</sup>   |
|           | 3    | 0.9 <sup>7</sup>    | 1.0 <sup>7</sup>    | 0.8 <sup>7</sup>     | 1.0 <sup>7</sup>    | 0.8 <sup>7</sup>    | 0.90 <sup>4</sup>   |
|           | 4    | 0.9 <sup>7</sup>    | 1.1 <sup>7</sup>    | 0.9 <sup>7</sup>     | 1.1 <sup>7</sup>    | 0.8 <sup>7</sup>    | 0.96 <sup>4</sup>   |
|           | 5    | 1.0 <sup>7</sup>    | 1.1 <sup>7</sup>    | 0.9 <sup>7</sup>     | 1.2 <sup>7</sup>    | 0.9 <sup>7</sup>    | 1.02 <sup>4</sup>   |
|           | 6    | 1.0 <sup>7</sup>    | 1.2 <sup>7</sup>    | 1.0 <sup>7</sup>     | 1.3 <sup>7</sup>    | 1.0 <sup>7</sup>    | 1.10 <sup>4</sup>   |
|           | 7    | 1.3 <sup>7</sup>    | 1.4 <sup>7</sup>    | 1.3 <sup>7</sup>     | 1.5 <sup>7</sup>    | 1.1 <sup>7</sup>    | 1.32 <sup>4</sup>   |
|           | 8    | 1.3 <sup>7</sup>    | 1.4 <sup>7</sup>    | 1.3 <sup>7</sup>     | 1.5 <sup>7</sup>    | 1.1 <sup>7</sup>    | 1.32 <sup>4</sup>   |
|           | 9    | 1.3 <sup>7</sup>    | 1.5 <sup>7</sup>    | 1.3 <sup>7</sup>     | 1.6 <sup>7</sup>    | 1.2 <sup>7</sup>    | 1.38 <sup>4</sup>   |
|           | 10   | 1.3 <sup>7</sup>    | 1.5 <sup>7</sup>    | 1.4 <sup>7</sup>     | 1.6 <sup>7</sup>    | 1.2 <sup>7</sup>    | 1.40 <sup>4</sup>   |
| MEAN      |      | 1.03 <sup>5</sup>   | 1.16 <sup>5</sup>   | 1.02 <sup>5</sup>    | 1.22 <sup>5</sup>   | 0.95 <sup>5</sup>   | 1.076 <sup>1A</sup> |
| DARK      | 1    | 0.5 <sup>7</sup>    | 0.5 <sup>7</sup>    | 0.5 <sup>7</sup>     | 0.5 <sup>7</sup>    | 0.5 <sup>7</sup>    | 0.50 <sup>4</sup>   |
|           | 2    | 0.6 <sup>7</sup>    | 0.6 <sup>7</sup>    | 0.6 <sup>7</sup>     | 0.6 <sup>7</sup>    | 0.6 <sup>7</sup>    | 0.60 <sup>4</sup>   |
|           | 3    | 0.7 <sup>7</sup>    | 0.6 <sup>7</sup>    | 0.6 <sup>7</sup>     | 0.7 <sup>7</sup>    | 0.6 <sup>7</sup>    | 0.64 <sup>4</sup>   |
|           | 4    | 0.7 <sup>7</sup>    | 0.7 <sup>7</sup>    | 0.7 <sup>7</sup>     | 0.7 <sup>7</sup>    | 0.6 <sup>7</sup>    | 0.68 <sup>4</sup>   |
|           | 5    | 0.7 <sup>7</sup>    | 0.7 <sup>7</sup>    | 0.7 <sup>7</sup>     | 0.7 <sup>7</sup>    | 0.6 <sup>7</sup>    | 0.68 <sup>4</sup>   |
|           | 6    | 0.8 <sup>7</sup>    | 0.7 <sup>7</sup>    | 0.8 <sup>7</sup>     | 0.7 <sup>7</sup>    | 0.6 <sup>7</sup>    | 0.72 <sup>4</sup>   |
|           | 7    | 0.8 <sup>7</sup>    | 0.7 <sup>7</sup>    | 0.8 <sup>7</sup>     | 0.8 <sup>7</sup>    | 0.7 <sup>7</sup>    | 0.76 <sup>4</sup>   |
|           | 8    | 0.8 <sup>7</sup>    | 0.8 <sup>7</sup>    | 0.8 <sup>7</sup>     | 0.8 <sup>7</sup>    | 0.7 <sup>7</sup>    | 0.78 <sup>4</sup>   |
|           | 9    | 0.9 <sup>7</sup>    | 0.8 <sup>7</sup>    | 0.9 <sup>7</sup>     | 0.8 <sup>7</sup>    | 0.8 <sup>7</sup>    | 0.84 <sup>4</sup>   |
|           | 10   | 1.0 <sup>7</sup>    | 0.9 <sup>7</sup>    | 0.9 <sup>7</sup>     | 0.8 <sup>7</sup>    | 0.8 <sup>7</sup>    | 0.80 <sup>8</sup>   |
| MEAN      |      | 0.75 <sup>5</sup>   | 0.7 <sup>5</sup>    | 0.73 <sup>5</sup>    | 0.71 <sup>5</sup>   | 0.65 <sup>5</sup>   | 0.708 <sup>1B</sup> |
| MEAN      |      | 0.89 <sup>3AB</sup> | 0.93 <sup>3AB</sup> | 0.875 <sup>3AB</sup> | 0.965 <sup>3A</sup> | 0.80 <sup>3B</sup>  | 0.892 <sup>1</sup>  |
| MEAN      | 1    | 0.55 <sup>6B</sup>  | 0.55 <sup>6B</sup>  | 0.55 <sup>6B</sup>   | 0.55 <sup>6B</sup>  | 0.55 <sup>6B</sup>  | 0.55 <sup>2B</sup>  |
|           | 2    | 0.65 <sup>6B</sup>  | 0.70 <sup>6B</sup>  | 0.65 <sup>6B</sup>   | 0.76 <sup>A</sup>   | 0.70 <sup>6B</sup>  | 0.68 <sup>2A</sup>  |
|           | 3    | 0.8 <sup>6B</sup>   | 0.80 <sup>6B</sup>  | 0.70 <sup>6B</sup>   | 0.85 <sup>6B</sup>  | 0.70 <sup>6B</sup>  | 0.77 <sup>2AB</sup> |
|           | 4    | 0.8 <sup>6B</sup>   | 0.90 <sup>6B</sup>  | 0.80 <sup>6B</sup>   | 0.90 <sup>6B</sup>  | 0.70 <sup>6B</sup>  | 0.82 <sup>2AB</sup> |
|           | 5    | 0.85 <sup>6B</sup>  | 0.90 <sup>6B</sup>  | 0.80 <sup>6B</sup>   | 0.95 <sup>6B</sup>  | 0.75 <sup>6</sup>   | 0.85 <sup>2AB</sup> |
|           | 6    | 0.9 <sup>6B</sup>   | 0.95 <sup>6B</sup>  | 0.90 <sup>6B</sup>   | 1.00 <sup>6AB</sup> | 0.80 <sup>6B</sup>  | 0.91 <sup>2AB</sup> |
|           | 7    | 1.05 <sup>6AB</sup> | 1.05 <sup>6AB</sup> | 1.05 <sup>6AB</sup>  | 1.15 <sup>6AB</sup> | 0.90 <sup>6B</sup>  | 1.04 <sup>2A</sup>  |
|           | 8    | 1.05 <sup>6AB</sup> | 1.10 <sup>6AB</sup> | 1.05 <sup>6AB</sup>  | 1.15 <sup>6AB</sup> | 0.90 <sup>6B</sup>  | 1.05 <sup>2A</sup>  |
|           | 9    | 1.1 <sup>6AB</sup>  | 1.15 <sup>6</sup>   | 1.10 <sup>6AB</sup>  | 1.20 <sup>6AB</sup> | 1.00 <sup>6B</sup>  | 1.11 <sup>2A</sup>  |
|           | 10   | 1.15 <sup>6AB</sup> | 1.20 <sup>6AB</sup> | 1.15 <sup>6AB</sup>  | 1.20 <sup>6AB</sup> | 1.00 <sup>6AB</sup> | 1.14 <sup>2A</sup>  |

<sup>A</sup> Condition, <sup>B</sup> Duration (time), <sup>C</sup> Method, <sup>D</sup> Condition x Time, <sup>E</sup> Condition x Method, <sup>F</sup> Time x Method, <sup>G</sup> Condition x Time x Method.

When the analysis of variance (ANOVA) table for free fatty acidity was examined, the highest mean value with respect to storage condition was observed in olive oils stored under light conditions (1.076), whereas the lowest value was recorded under dark conditions (0.708). The difference between these two storage conditions was

found to be statistically significant ( $F = 60.25$ ).

In terms of storage duration, the ANOVA results for free fatty acidity indicated that the highest value was obtained at the 10th measurement (1.14), while the lowest value was observed at the 1st measurement (0.55). This effect was also statistically significant ( $F = 4.31$ ).

According to the analysis of variance (ANOVA) table, the interaction between storage condition and storage method was found to be statistically significant ( $F = 3.32$ ). Under light storage conditions, the lowest free fatty acidity value (0.95) was observed for the Y5 method, whereas the highest value (1.22) was recorded for the Y4 method. Under dark storage conditions, the lowest value (0.60) was again obtained with the Y5 method, while the highest value (0.75) was determined for the Y1 method.

Based on the results of the present study, it was concluded that, in terms of free fatty acidity, olive oils should preferably be stored for a certain period under dark conditions and in tin containers to minimize quality deterioration.

Keçeli (2008) similarly reported that olive oils should be stored in dark environments to slow down deterioration. In addition, (Li and Wang, 2018) found that olive oils stored at 30°C under light conditions and at 2°C under dark conditions maintained their quality for a longer period when stored in the dark environment, which supports the findings of the present study.

In a study conducted by (Mendez and Falqué, 2006), olive oil was stored under commercial shelf conditions in transparent PET bottles, aluminum-coated PET bottles, glass bottles, tin containers, and Tetra Brik packages (multi-layered cartons composed of paperboard, polyethylene, and aluminum). The samples were maintained under the same temperature and light conditions for periods of three and six months, after which quality control analyses were performed. The results indicated that olive oils stored in tin and Tetra Brik containers under light and temperature exposure similar to commercial retail conditions did not exhibit significant quality deterioration. In contrast, olive oils stored in glass and PET bottles showed a gradual decline in quality over time.

These findings are consistent with and supportive of the results obtained in the present study.

The results of the analysis of variance for peroxide value are presented in *Table 4*, and the multiple comparison results are given in *Table 5*.

**Table 4. Analysis of Variance for Peroxide Value**

| Source of Variation       | Degrees of Freedom | Sum of Squares | Mean Square | F Value  | P Value |
|---------------------------|--------------------|----------------|-------------|----------|---------|
| Time                      | 9                  | 116.99230      | 12.99914    | 608.38   | 0.001*  |
| Condition                 | 1                  | 184.86750      | 184.86750   | 8652.145 | 0.001*  |
| Method                    | 4                  | 11.79913       | 3.9169731   | 138.05   | 0.001*  |
| Time x Condition          | 9                  | 19.25417       | 2.1392522   | 100.125  | 0.001*  |
| Time x Method             | 36                 | 4.49087        | 0.1247463   | 5.83     | 0.001*  |
| Condition x Method        | 4                  | 19.60500       | 4.90125     | 229.38   | 0.001*  |
| Time x Condition x Method | 36                 | 5.39167        | 0.1497686   | 7.009    | 0.001*  |

\*Indicates statistical significance at the  $p < 0.05$  level.

When the analysis of variance (ANOVA) table for peroxide value was examined, the highest mean value with respect to storage condition was observed in olive oils stored under light conditions (8.7), whereas the lowest value was recorded under dark conditions (7.2). The difference between the two storage conditions was found to be statistically significant ( $F = 8652.145$ ).

**Table 5. Tukey's HSD Multiple Comparison Test for Peroxide Value**

| Condition | Time | Y1                   | Y2                    | Y3                   | Y4                    | Y5                     | Mean                |
|-----------|------|----------------------|-----------------------|----------------------|-----------------------|------------------------|---------------------|
| LIGHT     | 1    | 6.6 <sup>7 F-J</sup> | 6.7 <sup>7 E-J</sup>  | 6.7 <sup>7 E-J</sup> | 6.7 <sup>7 E-J</sup>  | 6.5 <sup>7 G-J</sup>   | 6.6 <sup>4 N</sup>  |
|           | 2    | 7.8 <sup>7 R-Z</sup> | 8.0 <sup>7 P-X</sup>  | 6.9 <sup>7 U-Z</sup> | 8.3 <sup>7 N-S</sup>  | 7.9 <sup>7 R-Z</sup>   | 7.8 <sup>4 H</sup>  |
|           | 3    | 8.0 <sup>7 P-W</sup> | 8.7 <sup>7 J-N</sup>  | 7.9 <sup>7 Q-Y</sup> | 9.1 <sup>7 H-L</sup>  | 8.4 <sup>7 N-R</sup>   | 8.4 <sup>4 G</sup>  |
|           | 4    | 8.1 <sup>7 O-U</sup> | 9.2 <sup>7 G-J</sup>  | 8.0 <sup>7 P-V</sup> | 9.1 <sup>7 H-L</sup>  | 8.8 <sup>7 J-N</sup>   | 8.6 <sup>4 F</sup>  |
|           | 5    | 8.3 <sup>7 N-T</sup> | 9.3 <sup>7 F-I</sup>  | 8.3 <sup>7 N-S</sup> | 9.3 <sup>7 F-I</sup>  | 9.2 <sup>7 G-K</sup>   | 8.9 <sup>4 E</sup>  |
|           | 6    | 8.4 <sup>7 N-Q</sup> | 9.6 <sup>7 C-H</sup>  | 8.4 <sup>7 N-Q</sup> | 9.5 <sup>7 F-I</sup>  | 9.6 <sup>7 D-H</sup>   | 9.1 <sup>4 D</sup>  |
|           | 7    | 9.1 <sup>7 H-K</sup> | 9.9 <sup>7 B-E</sup>  | 8.6 <sup>7 I-M</sup> | 10.5 <sup>7 A</sup>   | 9.9 <sup>7 B-E</sup>   | 9.6 <sup>4 A</sup>  |
|           | 8    | 8.5 <sup>7 N-P</sup> | 10.0 <sup>7 A-D</sup> | 8.6 <sup>7 M-O</sup> | 9.6 <sup>7 C-G</sup>  | 9.9 <sup>7 B-E</sup>   | 9.3 <sup>4 C</sup>  |
|           | 9    | 8.6 <sup>7 L-O</sup> | 10.1 <sup>7 A-C</sup> | 8.6 <sup>7 L-O</sup> | 9.8 <sup>7 B-F</sup>  | 9.9 <sup>7 B-E</sup>   | 9.4 <sup>4 BC</sup> |
|           | 10   | 8.7 <sup>7 J-N</sup> | 10.2 <sup>7 AB</sup>  | 8.7 <sup>7 K-N</sup> | 10.0 <sup>7 A-E</sup> | 9.9 <sup>7 B-E</sup>   | 9.5 <sup>4 AB</sup> |
| MEAN      |      | 8.2 <sup>5 C</sup>   | 9.2 <sup>5 A</sup>    | 8.1 <sup>5 C</sup>   | 9.2 <sup>5 A</sup>    | 9.0 <sup>5 B</sup>     | 8.7 <sup>1 A</sup>  |
| DARK      | 1    | 6.5 <sup>7 H-J</sup> | 6.4 <sup>7 IJ</sup>   | 6.4 <sup>7 J</sup>   | 6.4 <sup>7 J</sup>    | 6.4 <sup>7 J</sup>     | 6.4 <sup>4 O</sup>  |
|           | 2    | 6.9 <sup>7 A-I</sup> | 6.9 <sup>7 C-J</sup>  | 6.7 <sup>7 D-J</sup> | 6.7 <sup>7 D-J</sup>  | 6.5 <sup>7 H-J</sup>   | 6.7 <sup>4 MN</sup> |
|           | 3    | 7.1 <sup>7 A-F</sup> | 7.1 <sup>7 B-J</sup>  | 6.9 <sup>7 A-I</sup> | 6.7 <sup>7 E-J</sup>  | 7.1 <sup>7 C-J</sup>   | 7.0 <sup>4 LM</sup> |
|           | 4    | 7.1 <sup>7 A-F</sup> | 7.1 <sup>7 A-H</sup>  | 7 <sup>7 A-H</sup>   | 6.8 <sup>7 D-J</sup>  | 7.2 <sup>7 AB-EE</sup> | 7.0 <sup>4 KL</sup> |
|           | 5    | 7.2 <sup>7 A-D</sup> | 7.2 <sup>7 A-G</sup>  | 7.2 <sup>7 A-D</sup> | 6.9 <sup>7 B-J</sup>  | 7.3 <sup>7 ABC</sup>   | 7.2 <sup>4 K</sup>  |
|           | 6    | 7.5 <sup>7 X-Z</sup> | 7.2 <sup>7 A-D</sup>  | 7.4 <sup>7 AB</sup>  | 7.1 <sup>7 A-F</sup>  | 7.4 <sup>7 YZ</sup>    | 7.3 <sup>4 J</sup>  |
|           | 7    | 7.5 <sup>7 W-Z</sup> | 7.4 <sup>7 V-Z</sup>  | 7.4 <sup>7 W-Z</sup> | 7.6 <sup>7 V-Z</sup>  | 7.5 <sup>7 S-Z</sup>   | 7.5 <sup>4 I</sup>  |
|           | 8    | 7.6 <sup>7 U-Z</sup> | 7.5 <sup>7 Z</sup>    | 7.5 <sup>7 V-Z</sup> | 7.6 <sup>7 X-Z</sup>  | 7.5 <sup>7 X-Z</sup>   | 7.5 <sup>4 IJ</sup> |
|           | 9    | 7.8 <sup>7 T-Z</sup> | 7.5 <sup>7 X-Z</sup>  | 7.6 <sup>7 V-Z</sup> | 7.6 <sup>7 V-Z</sup>  | 7.5 <sup>7 V-Z</sup>   | 7.6 <sup>4 I</sup>  |
|           | 10   | 7.8 <sup>7 S-Z</sup> | 7.6 <sup>7 V-Z</sup>  | 7.6 <sup>7 U-Z</sup> | 7.6 <sup>7 V-Z</sup>  | 7.6 <sup>7 V-Z</sup>   | 7.6 <sup>4 I</sup>  |
| MEAN      |      | 7.3 <sup>5 D</sup>   | 7.19 <sup>5 EF</sup>  | 7.1 <sup>5 DEF</sup> | 7.1 <sup>5 F</sup>    | 7.1 <sup>5 DE</sup>    | 7.2 <sup>1 B</sup>  |
| MEAN      |      | 7.8 <sup>3 B</sup>   | 8.2 <sup>3 A</sup>    | 7.6 <sup>3 B</sup>   | 8.1 <sup>3 A</sup>    | 8.1 <sup>3 A</sup>     |                     |
| MEAN      | 1    | 6.6 <sup>6 X</sup>   | 6.6 <sup>6 X</sup>    | 6.6 <sup>6 X</sup>   | 6.6 <sup>6 X</sup>    | 6.5 <sup>6 X</sup>     | 6.5 <sup>2 I</sup>  |
|           | 2    | 7.4 <sup>6 U-W</sup> | 7.5 <sup>6 T-W</sup>  | 6.8 <sup>6 VW</sup>  | 7.5 <sup>6 R-W</sup>  | 7.2 <sup>6 W</sup>     | 7.3 <sup>2 H</sup>  |
|           | 3    | 7.6 <sup>6 Q-V</sup> | 7.9 <sup>6 M-R</sup>  | 7.4 <sup>6 S-W</sup> | 7.9 <sup>6 L-P</sup>  | 7.7 <sup>6 P-U</sup>   | 7.7 <sup>2 G</sup>  |
|           | 4    | 7.6 <sup>6 P-U</sup> | 8.2 <sup>6 G-N</sup>  | 7.5 <sup>6 R-W</sup> | 8.0 <sup>6 J-P</sup>  | 8.0 <sup>6 H-P</sup>   | 7.8 <sup>2 F</sup>  |
|           | 5    | 7.8 <sup>6 O-T</sup> | 8.3 <sup>6 F-L</sup>  | 7.8 <sup>6 N-S</sup> | 8.1 <sup>6 G-M</sup>  | 8.3 <sup>6 E-J</sup>   | 8.0 <sup>2 E</sup>  |
|           | 6    | 8.0 <sup>6 I-P</sup> | 8.4 <sup>6 D-G</sup>  | 7.9 <sup>6 K-Q</sup> | 8.3 <sup>6 E-H</sup>  | 8.5 <sup>6 C-F</sup>   | 8.2 <sup>2 D</sup>  |
|           | 7    | 8.3 <sup>6 E-H</sup> | 8.7 <sup>6 A-D</sup>  | 8.0 <sup>6 E-K</sup> | 9.1 <sup>6 A</sup>    | 8.7 <sup>6 A-C</sup>   | 8.5 <sup>2 A</sup>  |
|           | 8    | 8.1 <sup>6 H-O</sup> | 8.8 <sup>6 A-C</sup>  | 8.1 <sup>6 H-O</sup> | 8.6 <sup>6 B-D</sup>  | 8.7 <sup>6 B-D</sup>   | 8.4 <sup>2 C</sup>  |
|           | 9    | 8.2 <sup>6 F-L</sup> | 8.8 <sup>6 A-C</sup>  | 8.1 <sup>6 G-M</sup> | 8.7 <sup>6 B-D</sup>  | 8.7 <sup>6 A-D</sup>   | 8.5 <sup>2 BC</sup> |
|           | 10   | 8.3 <sup>6 E-I</sup> | 8.9 <sup>6 AB</sup>   | 8.2 <sup>6 F-L</sup> | 8.8 <sup>6 A-C</sup>  | 8.8 <sup>6 A-D</sup>   | 8.6 <sup>2 AB</sup> |

<sup>A</sup> Condition, <sup>B</sup> Duration (time), <sup>C</sup> Method, <sup>D</sup> Condition x Time, <sup>E</sup> Condition x Method, <sup>F</sup> Time x Method, <sup>G</sup> Condition x Time x Method.

With respect to storage duration, the ANOVA results indicated that the highest peroxide value was obtained at the 10th measurement (8.6), while the lowest value was observed at the 1st measurement (6.5). This effect was also statistically significant ( $F = 608.38$ ).

When evaluated in terms of storage method, the lowest peroxide value (7.6) was observed in the Y3 method, whereas the highest value (8.2) was recorded in the Y2 method. The effect of method was statistically significant ( $F = 138.05$ ).

According to the ANOVA table, the interaction between time and storage condition was statistically significant ( $F = 100.125$ ). Under light conditions, the lowest peroxide value (6.6) was observed at the 1st measurement, while the highest value (9.5) was recorded at the 10th measurement. Under dark conditions, the lowest value (6.7) was also observed at the 1st measurement, whereas the highest value (7.6) was recorded at the 10th measurement.

The interaction between storage condition and storage method was likewise found to be statistically significant ( $F = 229.38$ ). Under light conditions, the lowest peroxide value (8.2) was observed in the Y1 method, while the highest value (10.2) was recorded in the Y2 method. Under dark conditions, the lowest value (7.1) was observed equally in the Y3, Y4, and Y5 methods, whereas the highest value (7.19) was found in the Y2 method.

When the interaction between time and storage method was examined, the ANOVA table indicated that this interaction was statistically significant ( $F = 5.83$ ). The highest peroxide value (8.9) was observed at the 10th measurement using the Y2 method, whereas the lowest value (6.5) was recorded at the 1st measurement using the Y5 method.

The three-way interaction among storage condition, time, and storage method was also found to be statistically significant for peroxide value ( $F = 7.009$ ). Under light conditions, the highest value (10.0) was observed at the 10th measurement using the Y4 method, while the lowest value (6.5) was recorded at the 1st measurement using the Y5 method. Under dark conditions, the highest value (7.8) was observed at the 9th and 10th measurements using the Y1 method. The lowest value (6.4) was recorded at the 1st measurement and was equal across the Y2, Y3, Y4, and Y5 methods.

During olive oil storage, deterioration may occur due to exposure to oxygen, metal ions, heat, temperature fluctuations, and similar factors. According to the results of this study, peroxide values remained below the maximum limit of 20 meq  $O_2$   $kg^{-1}$  specified in the Turkish Food Codex Communiqué on Olive Oil and Olive Pomace Oil, and no evidence of severe deterioration was detected. However, it was observed that peroxide values increased as storage duration extended. Therefore, it is recommended that olive oil be consumed within a short period after opening and be stored under dark conditions, preferably in glass or tin containers, to maintain quality.

The observation that the highest peroxide value was obtained in colored plastic bottles and the lowest value in transparent glass bottles may be attributed to the fact that olive oils exposed to direct sunlight undergo accelerated oxidation. Dark-colored containers may increase internal temperature through heat absorption under direct sunlight exposure, potentially accelerating oxidation reactions, which consequently affects the overall peroxide values.

In a study conducted by (Dabbou et al., 2011) on Tunisian olive oils, samples were stored for 12 months under diffuse light conditions (day and night) at room temperature (25°C) in stainless steel containers, jars, transparent PET bottles, transparent glass bottles, and dark-colored glass bottles. Quality analyses were performed at three-month intervals. The results showed that peroxide values increased progressively in dark-colored glass bottles and reached higher levels compared to the other storage methods. In jar-stored oils, peroxide values increased during the first three months and then continued to rise gradually over time.

Similarly, (El Yamani et al., 2022) reported that peroxide values of Moroccan Picholine olive oils increased significantly as storage duration extended. They also indicated that olive oils stored at 4°C under dark conditions preserved their quality more effectively than those stored under other conditions.

Similarly, (Kiritsakis et al., 1998) reported that olive oils should be stored in dark environments in order to slow down deterioration processes.

In another study, (Vacca et al., 2006) investigated changes in quality parameters, antioxidant compounds, oxidative stability, and antioxidant activity of monovarietal extra virgin olive oil obtained from the Bosana cultivar during an 18-month storage period under light and dark conditions. Their findings revealed significant changes in all evaluated parameters during storage. They also reported that oils meeting the direct consumption criteria (free acidity  $\leq 0.8\%$  and peroxide value  $\leq 20$  meq  $O_2$   $kg^{-1}$ ) maintained their quality more effectively when stored in dark conditions.

The consistency between these published findings and the results of the present study strengthens the validity of our conclusions.

#### 4. Conclusions

In this study, the effects of different packaging materials and storage conditions on the free fatty acidity and peroxide values of olive oils with a commercially declared shelf life of two years were evaluated over a ten-month storage period.

The results demonstrated that olive oils stored in dark-colored PET bottles under direct sunlight reached the upper

limit of the “virgin olive oil” classification (0.8% free fatty acidity) as early as the second measurement period. Although peroxide values remained below the maximum limit of 20 meq O<sub>2</sub> kg<sup>-1</sup> specified by the Turkish Food Codex, indicating no severe oxidation, the highest peroxide value under dark conditions (7.8 meq O<sub>2</sub> kg<sup>-1</sup>) was recorded at the 9th and 10th measurements in olive oils stored in transparent PET bottles.

Furthermore, olive oils stored in dark-colored glass bottles under light exposure exhibited a marked increase in both free fatty acidity and peroxide values. The elevated quality parameters observed in dark-colored glass bottles under light exposure may be attributed to heat absorption by the darker material absorbing heat, thereby accelerating oxidative degradation.

It can also be inferred that the rapid increase in acidity and peroxide values may be associated with insufficient clarification during packaging, particularly if suspended sediment remains in the oil. Given the acidic nature of olive oil, products stored in PET bottles or metal containers exposed to direct sunlight should not be commercially marketed under such conditions.

On the other hand, considering that olive oils stored in dark glass bottles may experience quality deterioration in the presence of heat and light due to heat absorption, it can be assessed that olive oils stored at room temperature, even in dark conditions, may not reliably maintain their quality for the two-year shelf life commonly stated in the market.

Based on the overall results, the most appropriate storage condition for preserving olive oil quality is under dark conditions, at temperatures below standard room temperature, and preferably in suitable glass or metal containers that minimize exposure to heat, light, and oxygen.

#### **Ethical Statement**

There is no need to obtain permission from the ethics committee for this study.

#### **Conflicts of Interest**

We declare that there is no conflict of interest between us as the article authors.

#### **Authorship Contribution Statement**

Concept: Sağlam, C., Gürocak, D.; Design: Sağlam, C., Gürocak, D.; Data Collection or Processing: Sağlam, C., Gürocak, D.; Statistical Analyses: Tuna, Y. T., Sağlam, C., Gürocak, D.; Literature Search: Sağlam, C., Gürocak, D.; Writing, Review and Editing: Sağlam, C., Tuna, Y. T., Gürocak, D.

## References

- Anonim (2021). International Olive Council (IOC). <https://www.internationaloliveoil.org/olive-oil-2021-22-crop-year>
- Aydınoğlu, Ü. (2009). Olive Oil and Wine Production in Mountainous Cilicia During Antiquity: Archaeological Evidence of Production, Ege Yayınları, İstanbul, Türkiye.
- Dabbou, S., Gharbi, I., Dabbou, S., Brahmi, F., Nakbi, A. and Hammami, M. (2011). Impact of packaging material and storage time on olive oil quality. *African Journal of Biotechnology*, 10: 16937-16947.
- El Yamani, M., Sakar, E. H., Boussakuran, A. and Rharrabti, Y. (2022). Effect of storage time and conditions on the quality characteristics of 'Moroccan Picholine' olive oil. *Biocatalysis and Agricultural Biotechnology*, 39: 102261.
- Jackson, R. (1999). Doctors and diseases in the Roman Empire. Homer Kitabevi, İstanbul, Türkiye.
- Kaleci, N. (2010). Konvansiyonel ve organik olarak yetiştirilen Ayvalık zeytin çeşidinin bazı meyve özellikleri, yağ asitleri ve tokoferol seviyelerinin belirlenmesi. *Zeytin Bilimi*, 1(2): 79-84.
- Kaplan, M. (2025). Evaluation of attitudes and knowledge levels of olive producers in the application of agricultural pharmaceuticals (Mardin Province). *Journal of Tekirdag Agricultural Faculty*, 22(1): 74- 87.
- Kaplan, M. and Arıhan, K. S. (2012). A healing source from antiquity to the present: The use of olive and olive oil in folk medicine. *Ankara University Journal of the Faculty of Languages, History and Geography*, 52(2): 41-56.
- Kara, H. H., Kırılan, M., Bayrak, A. and Dağdelen, A. (2011). Minor components of olive oil. *National Olive Congress*, 22-25 February, Akhisar, Manisa, Türkiye.
- Kayahan, M. and Tekin, A. (2006). Zeytinyağı Üretim Teknolojisi (pp. 131-166). Ankara, Türkiye.
- Keçeli, T. (2008). Zeytinyağının Depolanması ve Ambalajlanmasının Yağ Kalitesine Etkileri. *Türkiye 10. Gıda Kongresi*, 625-628, 21-23 Mayıs, Erzurum, Türkiye.
- Kiritsakis, A., Nanos, G. D., Polymenopoulos, Z., Thomai, T. and Sfakiotakis, E. (1998). Effect of fruit storage conditions on olive oil quality. *Journal of the American Oil Chemists Society*, 75(6): 721-724.
- Kıvrak, M. (2015). Zeytinyağı Kimyasal Analiz Yöntemleri ve Laboratuvar Uygulamaları [Ders notları]. Balıkesir Üniversitesi Edremit Meslek Yüksekokulu, Zeytincilik ve Zeytin İşleme Teknolojisi Programı, Edremit, Balıkesir, Türkiye.
- Li, X. and Wang, S. C. (2018). Shelf life of extra virgin olive oil and its prediction models. *Journal of Food Quality*, 2018: 1639260.
- Mendez, A. I. and Falqué, E. (2006). Effect of storage time and container type on the quality of extra-virgin olive oil. *Food Control*, 18: 521-529.
- Nurengin, M., Gülen, H., Çetin, Ö., Hakan, M., Güloğlu, U., Kaya, H. and Uluçay, N. (2023) frost tolerances of Turkish olive (*Olea europaea* L.) Cultivars. *Journal of Tekirdag Agricultural Faculty*, 20(2): 293-305.
- Öztürk, B., Dıraman, H. and Özdemir, D. (2014). Karanlık ve aydınlıkta depolanmış ayvalık ve memecik çeşidi natürel zeytinyağlarının spektroskopik verilere göre kemometrik sınıflandırılması. *Gıda (The Journal of Food)*, 39(2): 87-94.
- SAS Institute Inc. (1989). SAS/STAT User's Guide. Vol. 2, Version 6, 4th Edition, Cary, NC, U. S. A.
- Tunanoğlu, R., Yıldız Tiryaki, G., Tan, S. and Taşkaya, B. (2003). Developments in World Olive Oil Consumption and Changes in Turkish Olive Oil Consumption. *1st Turkish Olive Oil and Table Olive Symposium*, 2-3 October, İzmir, Türkiye.
- Vacca, V., Del Caro, A., Poiana, M. and Piga, A. (2006). Effect of storage period and exposure conditions on the quality of Bosana extra-virgin olive oil. *Journal of Food Quality*, 29: 139-150.