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Shelf Life Quality and Bioactive Constituents of Virgin Olive Oil Affected by Packaging Type and Storage Period

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Abstract

One of the few oils is virgin olive oil, consumed without any chemical treatment. It is likely that the actual storage period and packing type reflect actual changes in the virgin olive oil matrix. So, this work was carried out to study the effect of storage period and packaging container types on the bioactive constituents of virgin olive oil.

The results indicated that the storage period had a significant effect on the bioactive constituents of virgin olive oil. A gradual and significant decrease in total sterols, carotenoids, chlorophyll, polyphenols, and tocopherols occurred with a storage period of extended 6 months. There were significant differences in the bioactive constituents of olive oil among the storage containers, i.e., transparent glass, brown glass, transparent polyethylene terephalate brown polyethylene terephalate, and tinplate cans. Brown glass container recorded the lowest loss values of total sterol, carotenoids, and chlorophylls; however, the highest loss values were recorded for transparent polyethylene terephalate. Therefore, it is seen that the storage period and packaging type standards for virgin olive oil can be to meet consumer requirements. Tinplate cans recorded the lowest loss values of total polyphenols and tocopherols. There were significant interactions between storage period and container type for all bioactive constituents.

Therefore, it is seen that the storage period and packaging type standards for virgin olive oil can be to meet consumer requirements. Some olive oils stored in plastic bottles (the commercially traditional container) are not adequate for storage, and brown glass remains a better container under the study.

Keywords: Sterols, Carotenoids, Chlorophylls, Packaging and Storage period.

Introduction

Olive oil (*Olea europaea L.*) has beneficial health effects for humans, such as being antihypertensive, anticancer, hypoglycemic, neuroprotective, and anti-inflammatory. Olive oil's health benefits are mainly attributed to its high content of bioactive phytochemicals, including total sterols, carotenoids, chlorophyll, total phenols, and total tocopherols. For several thousand years, virgin olive oil (VOO) products have been widely used in folk medicine in Mediterranean countries, and numerous studies have demonstrated their potential as a source of bioactive constituents. Olive oil is represented as a superfood attributed to its health parameters derived from its unique composition (**Oliveras-López** et al., **2014; Vickers**, **2017; Mazivila, 2018; and Román** et al., **2019**).

The oxidation of lipids is the main cause of the reduced stability and quality of olive oil. It causes off-flavor or rancidity and decreases the nutritional value of some olive oil vitamins (i.e., A, D, E, and K). It led to health risks and even toxicity for humans. Products of lipid oxidation cause aging, carcinogenesis, and coronary heart disease. So, the health characteristics of VOO led to an increase in the consumption of olive oil throughout the world. The presence of bioactive constituents, such as total sterols, phenols, and tocopherols, in olive oil caused a shelf life than that of other plant oils (**Urpi-Sarda et al., 2012; Musumeci et al., 2013; and Jimenez-Lopez et al., 2020**).

Storage period and packaging type are considered critical factors that affect the olive oil's shelf life and quality. This could be attributed to mechanisms of lipid oxidation that lead to rancidity. Changes in oil quality are also reflected in standardized quality indices, oxidative stability, and levels of bioactive constituent levels with storage period (**Vacca et al., 2006; Vossen, 2007**). Olive oil is bottled in plastic, metal, or glass containers. The primary advantages of glass and metal containers (tinplate cans) are their impermeability to gases, but the transparent plastic and glass containers had some disadvantages, such as favoring photooxidation. The main function of packaging materials is related to their barrier characteristics against oxygen, moisture, and light. Tocopherols and polyphenols are the two main groups of bioactive constituents that act as primary antioxidants to inhibit oxidation in VOO (**Capriotti et al., 2014**).

The aim of this work was to study the quality of local VOO offered on the market as well as the effects of storage period and packaging container types on the bioactive constituents of VOO over a six-month period. in addition to shelf life quality and gaps that can spark new exploratory research.

Materials and Methods

During the 2020–2021 working season, this experiment was carried out in the Food Science and Technology, Department of Food and Agricultural Sciences of New Valley University, Egypt, for a 6-month period.

1. Materials and VOO Sampling

Commercial samples of VOO of the Picual variety produced during the December 2020 season were collected from a local oil mill in Farafra Oasis, New Valley Governorate, Egypt.

The containers used in this research were purchased from Trading and Packaging Materials Co., Assuit, Assiut City, Egypt.

El-Gomhouria Trading Chemicals and Drugs Co. in Assiut, Egypt, supplied the chemicals used in this study to determine the minor components of VOO.

2. Storage Conditions at Laboratory Scale

VOO (Visual Monovarietal) samples were bottled in five types of 500-ml containers, i.e., transparent glass (TG), brown glass (BG), transparent polyethylene terephalate (TPET), brown polyethylene terephalate (BPET), and tinplate cans, and stored for 6 months. All VOO samples were analyzed immediately after production in the December 2020 crop season (time 0) and then stored at room temperature (25–30 °C) for 6 months under commercial conditions. Storage conditions were chosen to emulate New Valley temperatures. Five batches were analyzed every 45 days (0, 45, 90, 135, and 180 days) of storage after production.

The closed olive oil containers were placed in the center of a chamber with glass windows at room temperature to ensure equal exposure to air and light (natural and fluorescent lamps). These conditions were chosen to simulate the actual situation in a marketplace (illumination 10–12 hours per day).

3. Analytical Determinations

3.1. Total sterols

About 200 mg of the sampled oil was placed in a 10 mL propylene tube. Then, 200 µL of an internal standard solution (5α-cholestan-3β-ol, Sigma-Aldrich) in hexane was added. The analysis of the unsaponifiable fraction was performed by GC according to the method of **Fernández-Cuesta, et al. (2013)** and **Mousavi, et al. (2019)** as mg kg−1.

3.2. Total chlorophylls and carotenoids

Total chlorophylls and carotenoids were determined at 670 nm and 470 nm, respectively, according to the method of Minguez-**Mosquera et al., (1992)** protocol as mg kg−1.

3.3. Total polyphenols

The content of total polyphenols was determined by the Folin–Ciocalteu (FC) method, according to the analytical protocol described by **Cinquanta et al. (1997)** and **Singleton et al. (1999),** and expressed in mg kg−1 of garlic acid (GA).

3.4. Tocopherols:

The tocopherol composition was determined by modifying the HPLC procedure described in **Tura et al. (2007)** and **Paez, et al., (2016)** as mg kg 1.

4. Statistical Analysis

ANOVA was used to analyses oil analytical characteristics data using CoSTAT. The statistical analysis of all results was carried out according to **Montgomery (2017).** Homogeneity of variance and differences among treatments were evaluated by the least significant difference (LSD) test at 5%.

Results and Discussion

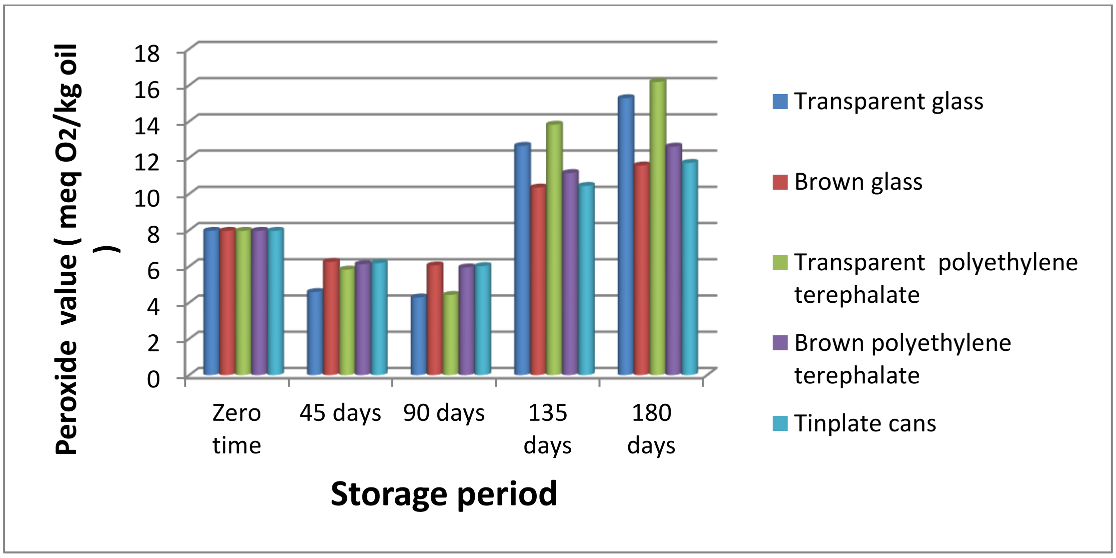

Fig. 1: Effect of storage period and type of packaging containers on peroxide value (meq O2 /kg oil) of VOO samples at room temperature.

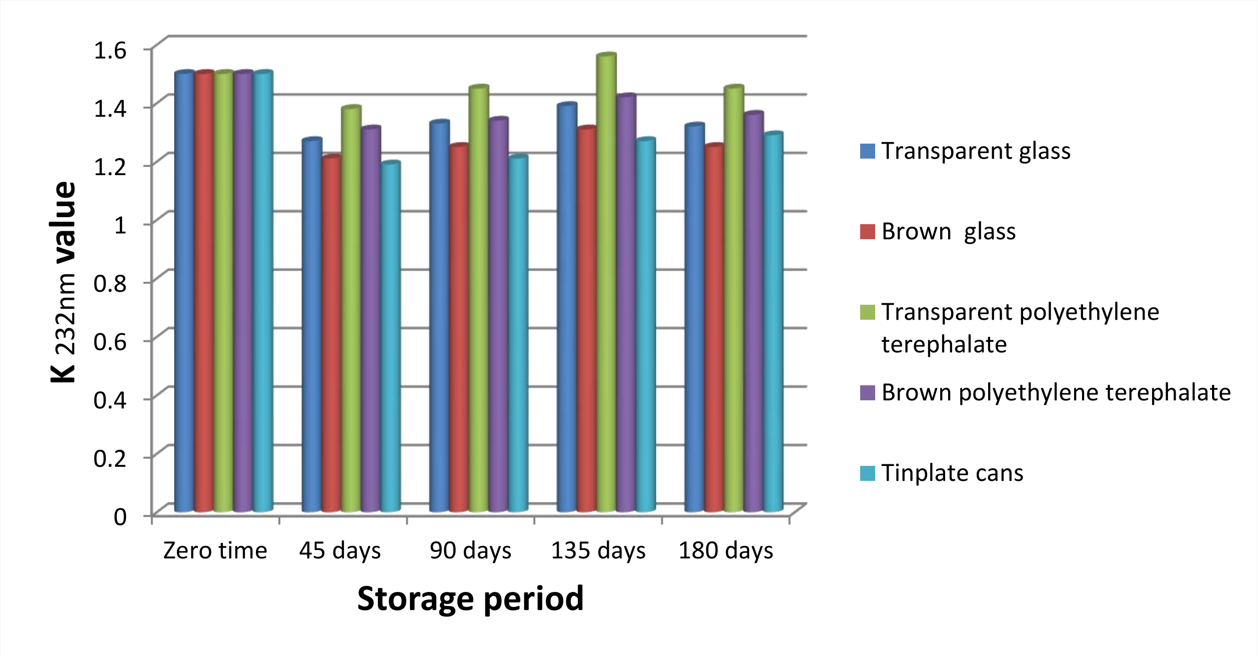

Fig. 2: Effect of storage period and packaging containers type on extinction coefficient (K232nm value) of VOO samples at room temperature.

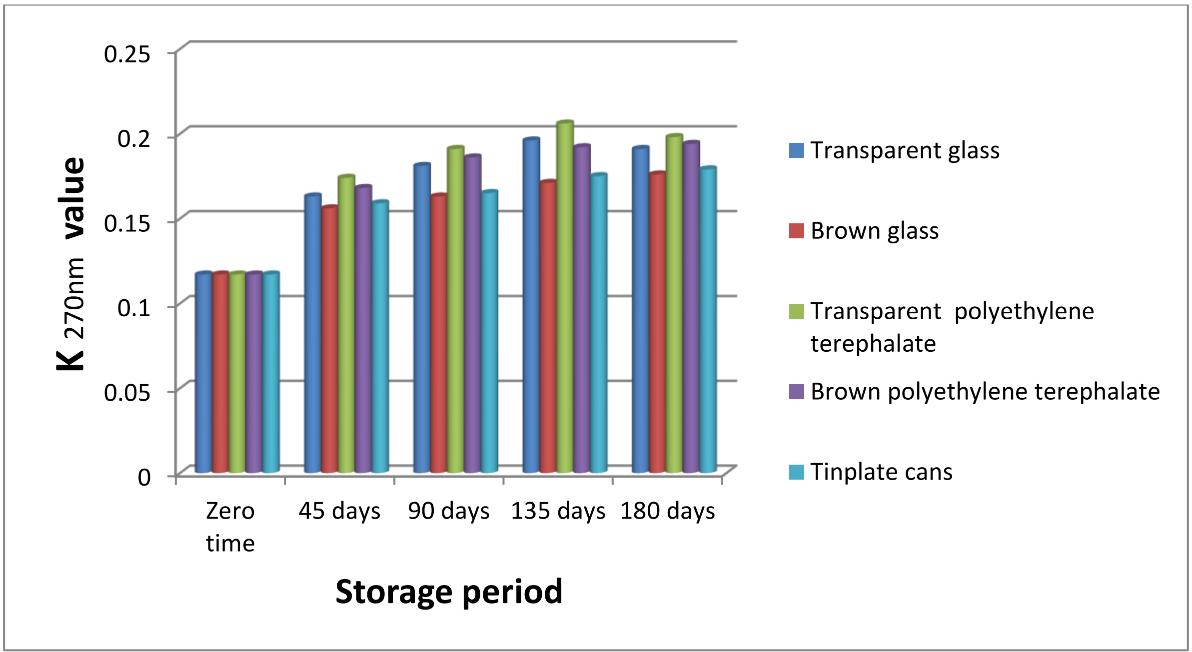

Fig.3: Effect of storage period and packaging containers type on extinction coefficient (K270nm value) of FVOO*samples at room temperature.

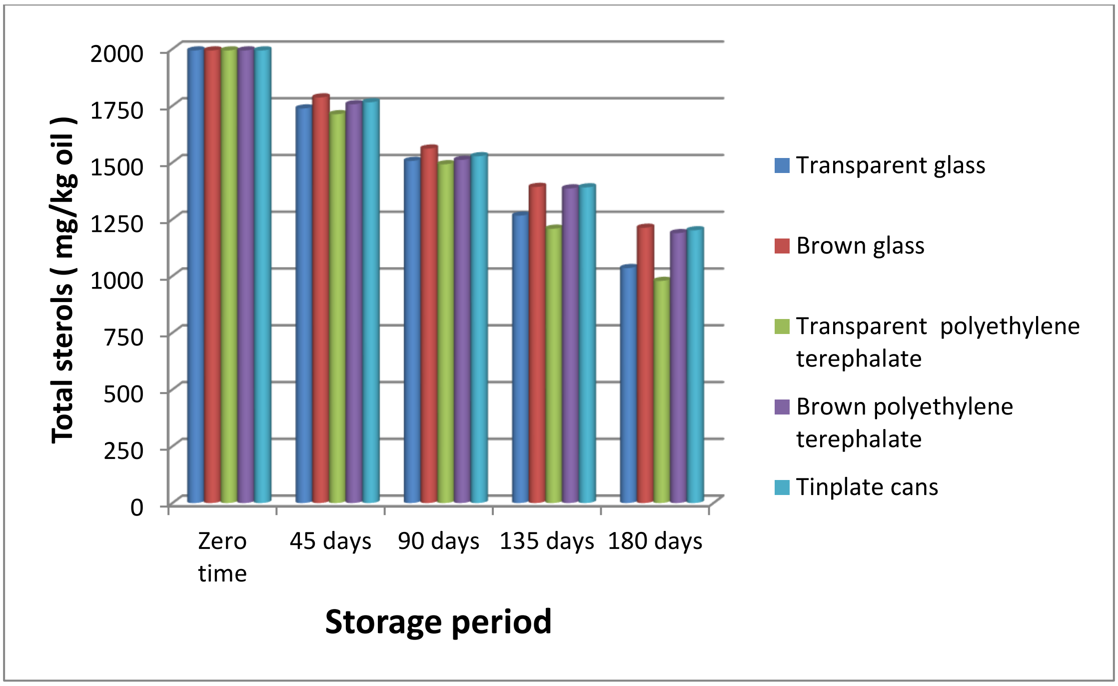

Fig. 4: Effect of storage period and packaging containers type on the total sterols (mg/kg oil) of VOO samples at room temperature.

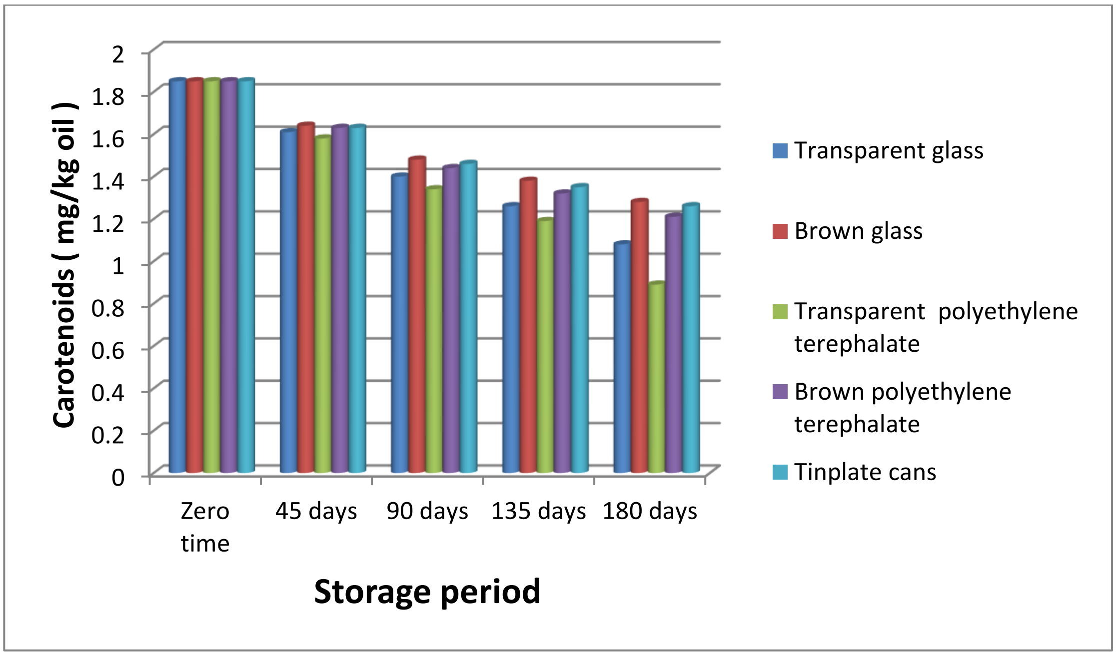

Fig.5: Effect of storage period and packaging containers type on the carotenoids (mg/kg oil) of VOO samples at room temperature.

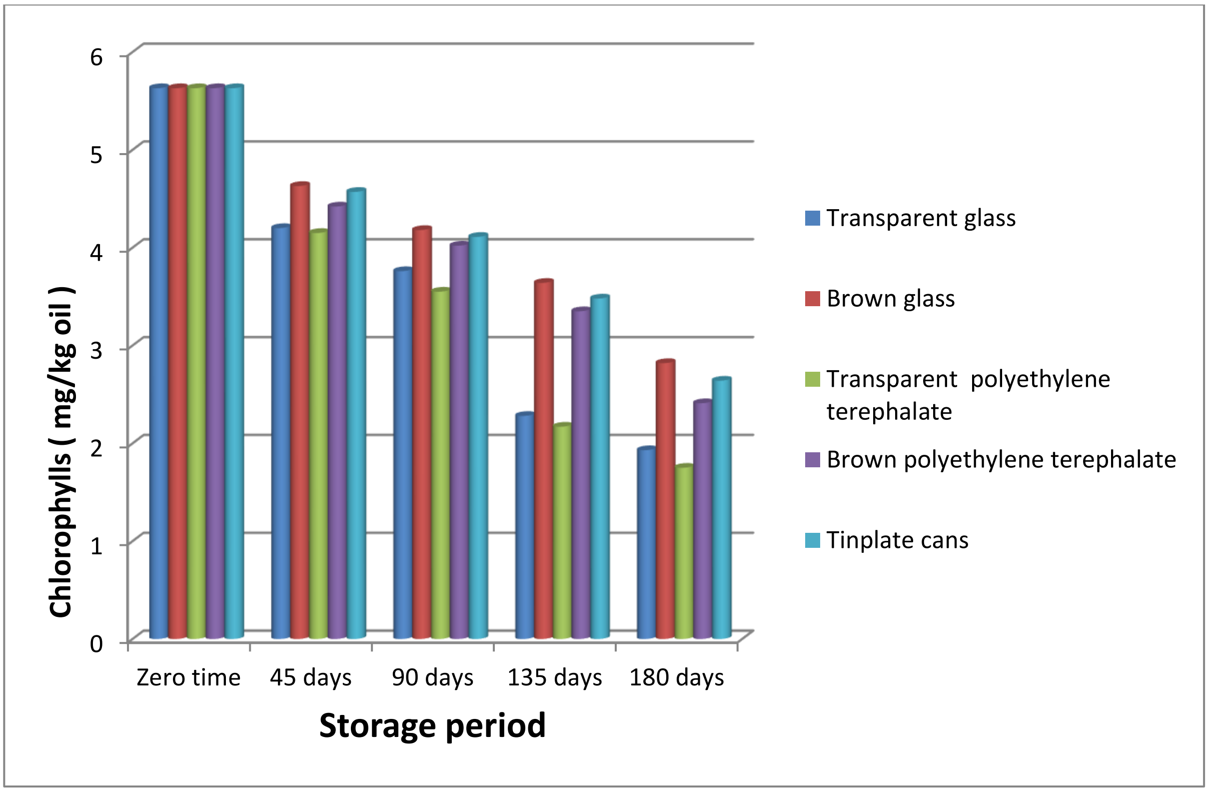

Fig. 6: Effect of storage period and packaging containers type on the total chlorophylls (mg/kg oil) of VOO samples at room temperature.

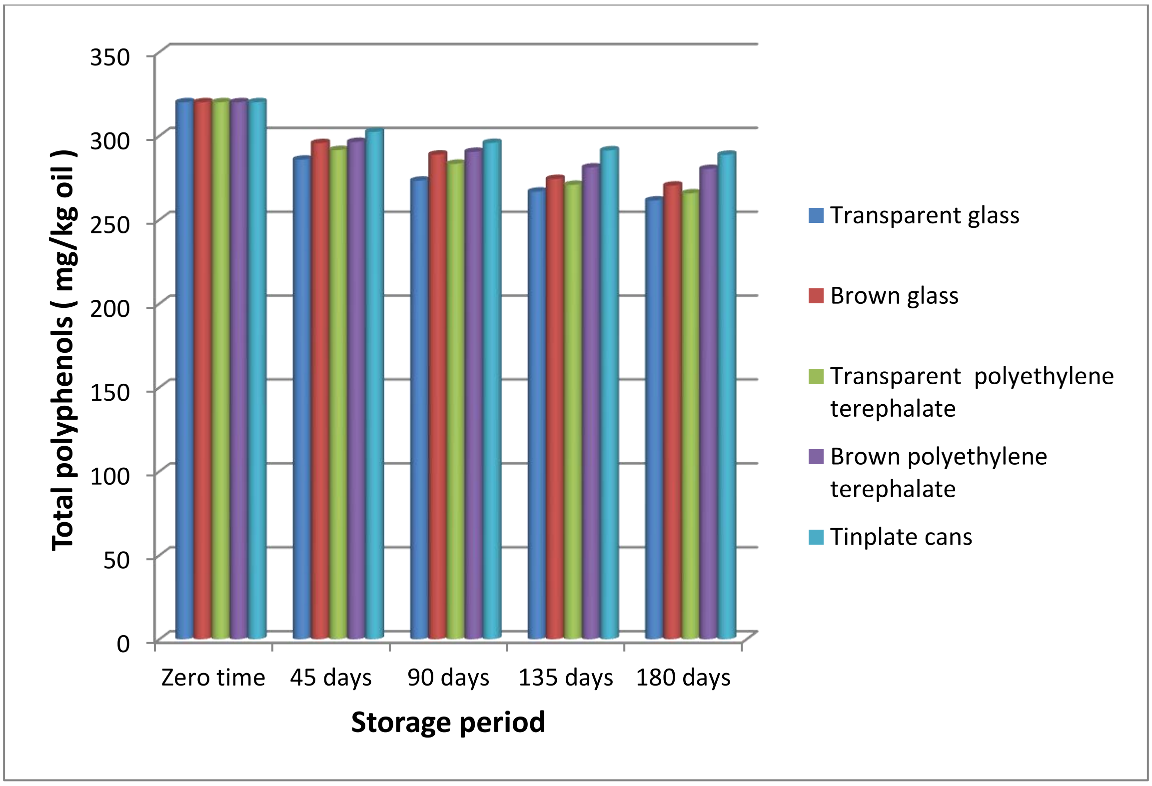

Fig. 7: Effect of storage period and packaging containers type on the total polyphenols (mg/kg GA oil) of VOO samples at room temperature.

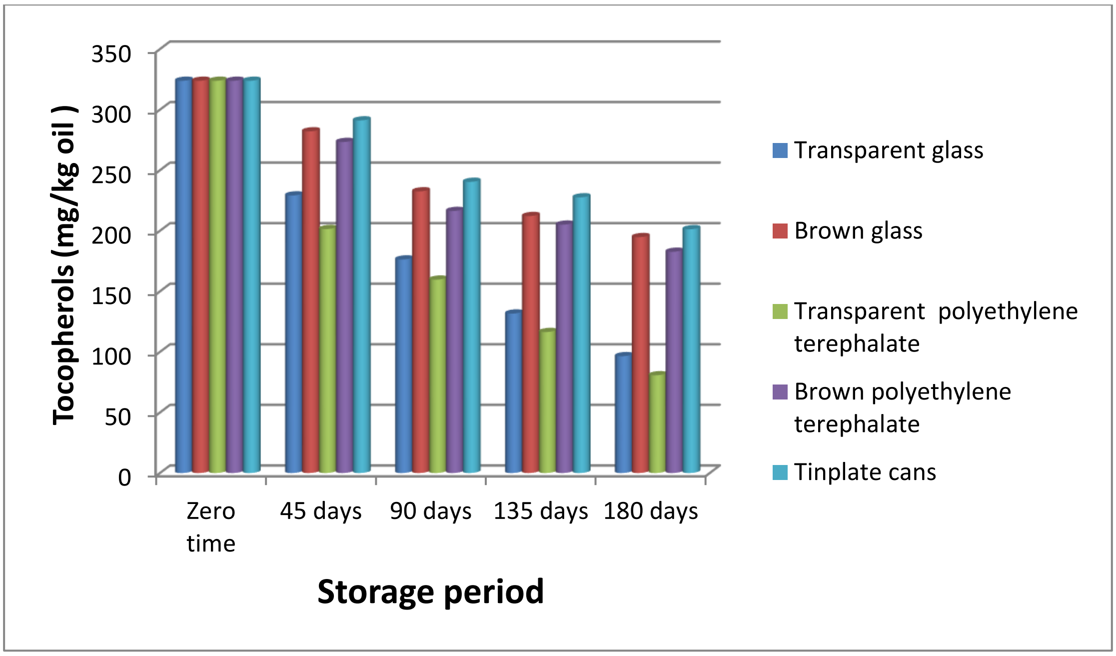

Fig. 8: Effect of storage period and packaging containers type on the total tocopherols (mg/kg oil) of VOO samples at room temperature.

The degradation of olive oil quality has been a challenge for manufacturers and food scientists alike. Figures 1–8 showed that the bioactive components of VOO, namely total sterols, carotenoids, chlorophylls, polyphenols, and tocopherols, gradually decreased from 1993.33 to 1123.06, 1.85 to 1.14, 5.63 to 2.31, 320.01 to 273.27, and 323.80 to 151.14 mg/kg oil, with increasing storage time from zero to 180 days, respectively. The decrease in bioactive compounds could be due to oil oxidation. The oxidative deterioration of olive oil during storage is prevented by the natural bioactive compounds found in the oil, especially polyphenols and tocopherols, which delay the production of undesirable volatile constituents. Bioactive constituents inhibit lipid oxidation because they act as natural antioxidants in oil. A sharp decrease in polyphenol content in all the samples during storage, reducing the stability and commercial quality of the VOO. Such data confirmed the previous trend with the results obtained by **Cinquanta, et al., (2001); Méndez & Falqué, (2007); Abbadi et al., (2014); Taoudiat et al. (2018); and Martn-Torres et al. (2022)**. They demonstrated that there were changes in olive oil's quality starting immediately after extraction as a result of lipid oxidation. Total carotenoids and chlorophylls, which belong to the unsaponifiable fraction naturally found in olives, act to increase the shelf life of stored oil. Bioactive compounds are considered to exert protective effects against many diseases due to their inhibition of oxidative damage. The green color of olive oil decreased as the oil ages, which might be attributed to the conversion of chlorophyll to other pigments, that is, pyropheophytins (PPP) and pheophytins (PP). The decrease in polyphenol compounds in olive oil occurs through photooxidation processes catalyzed by light and heat. In real time, the storage conditions of olive oil in supermarkets and hypermarkets are not optimum for the shelf life of VOO because it is exposed to light and high temperatures.

From the previous results in Figures 1–8, there were significant differences in bioactive constituents, ie, total sterols, carotenoids, chlorophylls, polyphenols and tocopherols of VOO samples, between the different storage containers in the studied storage periods. The VOO BG container recorded the lowest value (1589.09, 1.53, and 4.18 mg/kg oil) of total sterol, carotenoids, and chlorophylls, respectively. However, the highest value of these components (1476.88, 1.37, and 3.45 mg/kg oil) was recorded for the TPET container. The TC cans (TC) of VOO contained the highest values (299.63 and 256.80 mg / kg of oil) of total phenols and tocopherols, while the lowest values (281.45 and 176.38 mg / kg of oil) were recorded for TG containers and TPET, respectively. Similar findings were studied by **Méndez & Falqué (2007); Abbadi et al. (2014); and Zarazir et al. (2019).** They revealed that total chlorophylls and carotenoids decreased significantly in all samples during the accelerated oxidation test. The use of brown packaging containers allowed for a reduction in the degradation of chlorophylls and carotenoids in both BPET and glass bottles. The packaging material should ensure protection from storage conditions in order to maintain the olive oil's quality.

The data in Fig. 1–8 clarified that there was significant interaction between storage period and packaging container types with regard to bioactive constituents, i.e., total sterols, carotenoids, chlorophylls, polyphenols, and tocopherols of VOO samples. The highest values (1786.36, 1.64, and 4.63 mg/kg oil) of total sterols, carotenoids, and chlorophylls were recorded with a storage period of VOO for 45 days in a BG container. During the storage period of 180 days, the TPET container contained the lowest values (978.24 and 1.75 mg/kg oil) of total sterols, chlorophylls, respectively. The highest value (291.07 mg/kg oil) of total tocopherol content in VOO samples was recorded with a storage period of 45 days in a TC container, while, storage period of 180 days in a TPET container contained the lowest value (80.68 mg/kg oil). Such findings are in agreement with those obtained by **Méndez & Falqué (2007), Abbadi et al., (2014), and Zarazir et al. (2019).** They reported that certain components of VOO deteriorate under the presence of oxygen, but glass allows the direct action of light on the stored olive oil, and this could promote oxidative rancidity as a consequence of its sensibility to photooxidation. Additionally, in dark conditions, glass containers contained more polyphenol compounds than plastic containers; the reduction in antioxidants in plastic containers could be due to its permeability to oxygen and the migration of active compounds between oil and packaging material. The loss of total polyphenols was greater in the oil stored in TG and TPET. This can be explained by the effect of light on photooxidation of oil and the subsequent reduction of antioxidant compounds, including total polyphenols and tocopherols, as well as the greater light transparency of glass compared to TPET followed by BPET.

Conclusions

This research was carried out to evaluate the quality of local VOO offered to the market in New Valley Governorate, Egypt. So, it is worth controlling certain factors during storage, like oxygen presence, exposure to light, temperature, or the chosen packaging material, to maintain its quality and extend its shelf life until consumption. The plastic bottle (traditional container, i.e., plastic bottle) in which some VOOs are packaged commercially is seen to be not the most adequate for long-term storage. Glass remains a better container for VOO than polymeric materials at ambient storage temperatures and for extended periods of time. Some olive oils stored in plastic bottles are not suitable for storage, and BG remains a better container under the study. The green color of olive oil decreased as the oil aged, which might be attributed to the conversion of chlorophylls to other pigments, i.e., pheophytins (PP) and pyropheophytins (PPP).

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Conflicts of Interest/ Competing interest

The authors declare no conflict of interest. The funders had role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Abbreviations

VOO	Virgin Olive Oil
Ns	Non-significant
TG	Transparent Glass
BG	Brown glass.
TPET	Transparent polyethylene terephalate
BPET	Brown polyethylene terephalate
TC	Tinplate Cans
AOAC	Association of Official Analytical Chemists
GA	Gallic Acid.
FC	Folin–Ciocalteu
GC	Gas Chromatography
HPLC	High-Performance Liquid Chromatography
PP	Pheophytins
PPP	Pyropheophytins

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