Effects of type of packaging material on physicochemical and sensory properties of olive oil

Taha M. Rababah[1], Hao Feng[2], Wade Yang[3], Khalil Eriefej[1], Mohamad Al-Omoush[1]

(1. *Faculty of Agriculture*, *Jordan University of Science and Technology*, *P.O. Box 3030*, *Irbid 22110*, *Jordan*;
2. *Food and Bio-process Engineering*, *Department of Food Science and Human Nutrition*, *University of Illinois at Urbana-Champaign*, *382F Agricultural Engineering Sciences Building*, *Urbana*, *IL 61801*, *USA*;
3. *Food Processing Engineering*, *Department of Food Science and Human Nutrition*, *University of Florida*, *P.O. Box 110370*, *Gainesville*, *FL 32611-0370*, *USA*)

Abstract: This study was performed to evaluate changes in physicochemical and sensory attributes of olive oil stored in different packaging materials for up to 60 days. The olive oil samples from a local company (Ajlon-Jordan) were stored in containers made from glass, tinplate, and plastic for two months at 25℃ with quality attributes analyzed at selected time intervals. The results showed that as time increased from 0 to 60 days the acidity and peroxide values (PV) of the oil increased while antioxidant activities, total phenolics, and sensory attributes decreased. The samples in the glass container exhibited the lowest acidity (1.25% to 1.53%) and PV (6.13 to 7.17 milliequivalents meq/kg) values followed by those stored in the plastic and tinplate containers. The lowest antioxidant activities and total phenolics values were recorded in oil from the tinplate container while no significant difference ($p \leq 0.05$) was found for samples in the glass and plastic containers. The oil in the tinplate container had the highest values of sedimentation (0.17%). The glass container provided the best protection to oil samples as indicated by the best sensory properties, followed by plastic and tinplate containers.

Keywords: packaging, olive oil, antioxidants, sensory evaluation
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1 Introduction

Olive oil is a major agricultural commodity in Jordan. There are around 15 million olive trees in Jordan, and the number is increasing every year. More than 100 olive milling factories are currently in operation to process olive fruits.

Olive oil contains a broad spectrum of antioxidant nutrients that are not found in other oils. Especially, it is

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Biographies: Hao Feng, PhD, Associate Professor, Food and Bio-process Engineering, Department of Food Science and Human Nutrition, University of Illinois at Urbana-Champaign, 382F Agricultural Engineering Sciences Building, Urbana, IL 61801. Phone: (217) 244-2571; Fax: (217) 333-9329; E-mail: haofeng@illinois.edu; **Wade Yang**, PhD, Assistant Professor, Food Processing Engineering, Department of Food Science and Human Nutrition, University of Florida, P.O. Box 110370, Gainesville, FL 32611-0370. Phone: (352) 392-1991 | Fax: (352) 392-9467; Email: wade.yang@ufl.edu**. Khalil Eriefej,** PhD, Professor of Food Science, Faculty of Agriculture, Jordan University of Science and Technology, P.O. Box 3030, Irbid 22110, Jordan. Phone: + 962-2-7201000; Fax: + 962-2-7201078; Email: ereifej@just.edu.jo; Mohamad Al-Omoush, M.Sc., Technician in Plant Science, Faculty of Agriculture, Jordan University of Science and Technology, P.O. Box 3030, Irbid 22110, Jordan. Phone: + 962-2-7201000; Fax: + 962-2-7201078; Email: msa@just.edu.jo.

Corresponding author: Taha Rababah, PhD, Associate professor of Food processing, Faculty of Agriculture, Jordan University of Science and Technology, P.O. Box 3030, Irbid 22110, Jordan. Phone: 00962-2-7201000; Fax: 00962-2-7201087; Email: trababah@just. edu.jo or rebabah@yahoo.com.

rich in hydroxytyrosol, which is thought to be the main antioxidant compound in olives and plays an important role in the many health benefits attributed to olive oil. The beneficial health effects of olive oil also come from its high content of monounsaturated fatty acids, mainly oleic acid, which helps to protect against heart disease by controlling LDL cholesterol levels while raising HDL levels. The packaging of olive oil is of decisive importance due to the sensitivity of the oil to light- or oxygen-mediated quality degradation. Physical characteristics of the packaging material may directly affect the quality of oil[1]. Glass, metals and different kinds of plastic films (bottles) are all used for packaging of oil in Jordan. Glass has many advantages such as inertness and rigidity, but is costly and brittle. Plastic bottles are used extensively for packing due to their outstanding functionality. However, they offer limited protection to the oil due to less superior barrier properties compared to glass and tinplate. Packaging can directly influence olive oil quality by protecting the product from both oxygen and light[2]. Materials which have been used for olive oil packaging include glass, metals tin-coated steel, and more recently plastics and plastics coated paperboard[3]. Among plastics, polyethylene packaging has captured a large portion of the olive oil retail market due to its many advantages including clarity, chemical inertness, low oxygen permeability, and excellent mechanical properties[4]. Therefore, they are not always suitable for this purpose.

The impact of packaging materials on the quality of olive oil is important for oil producers, consumers, and food manufactures that use olive oil in their products. Not many studies have been conducted over the years to examine the quality changes of packaged olive oil during storage with both chemical analysis and human panels. The main conventional methods used to evaluate olive oil quality include acidity determination, color, viscosity, PV, conductivity methods (Rancimat-OSI) and sensory evaluation. Olive oil quality is defined from commercial, nutritional and sensory perspectives[5]. The nutritional value of olive oil is because of its high content of monounsaturated oleic acid and minor nutraceutical constituents, and its sensory properties[6,7]. One of the most widely used tests for oxidative rancidity; PV is a measure of the concentration of peroxides and hydroperoxides formed in the initial stages of lipid oxidation[8]. Oxidation constitutes a major factor for quality deterioration of olive oil[9]. It may lead to the development of rancid off-flavors, cause changes in color, reduce shelf life, and/or impair nutritional quality[10,11].

The few studies published about the effect of packaging on oil quality have concluded that stability can be enhanced by suitable selection of packaging[1,3,4]. The aim of the present work was therefore to examine the effect of selected packaging materials (Glass, metal, and plastic) on the quality of olive oil during storage by studying the physicochemical and sensory properties.

2 Materials and methods

2.1 Materials

The Nabali olive oil and glass, tinplate, and plastic containers were obtained from an industrial mill (Alkhair Walbaraka Company, Ajloun, Jordan). Butylated hydroxyl toluene (BHT) purchased from Sigma-Aldrich agent (Amman-Jordan). All solvents and chemicals used for the chemical determination were of analytical grade and purchased from local chemical suppliers (Irbid –Jordan).

2.2 Methods

2.2.1 Experimental set up – packaging materials

Three types of containers included tinplate, polypropylene (PP) and clear glass bottles, 2.5 L in capacity, were filled with olive oil and closed tightly. Triplicate of these packaged samples were stored for 0, 15, 30, 45, and 60 days at room temperature (25℃) and evaluated for physicochemical (PV, acidity, total phenolics, antioxidant activity, and sedimentation) and sensory properties.

2.2.2 PV and acidity analysis

PV and acidity analysis were carried out according to the procedures outlined by the AOAC[12] .

2.2.3 Sedimentation measurements

Sedimentation of olive oil was measured and expressed as (%) using a modified centrifugation methods. Twenty millimeters of olive oil was centrifuged at 3 000 r/min for 15 min. The clear upper layers were removed and the rest were calculated and expressed as sedimentation (%).

2.2.4 Determination of total phenolics

Olive oil in each type of packaging was used for determination of total phenolics by the Folin- Ciocalteu method[13]. Fifty milligrams of each sample was weighed into 50 mL plastic extraction tubes and vortexed with 25 mL of the extraction solvent (50 mL acetone: 50 mL methanol: 0.1 mL formic acid). Then, the sample with the extraction solvent were heated at 60℃ (water bath) for 1 h, allowed to cool to room temperature, and homogenized for 30 s with sonicator at setting 6. The homogenized sample was filtered through Miracloth into a screw-capped test tube.

Filtrates from each extract (200 μL, three replicates) were introduced into screw-cap test tubes; 1.0 mL of Folin-Ciocalteu's reagent and 1.0 mL of sodium carbonate (7.5%) were added. The tubes were vortexed and allowed to stand for 2 h. Absorption at 726 nm was measured with a spectrophotometer. The total phenolic content was expressed as chlorogenic acid equivalents (CAE) in milligrams per gram of dry material.

Total Phenolics Concentration in mg/100g=

$(A/b)*[(SW+25)/SW]*100$

where, A= absorbance at 726 nm; SW= sample weight, g; b= slope of the standard curve of chlorogenic acid.

2.2.5 Antioxidant activity determination

DPPH radical scavenging effect was determined according to the method of Matthäus[14]. DPPH is widely used to test the ability of compounds to act as hydrogen donors or free radical scavengers, and to evaluate antioxidant activity of foods.

Approximately 6 mL in triplicate of each sample were extracted under stirring with 50 mL methanol for 60 min, at 60℃. Different levels of methanol extracts and IC_{50} of each sample were reacted with 0.2 mL of DPPH solution (50 mg of DPPH in 100 mL of methanol). The mixture was brought to a total volume of 4 mL with methanol. The mixture was allowed to settle in the dark for 30 min. Absorbance (A) then was read at 515 nm, against the blank (methanol); a blank was used to remove the influence of the color of the samples. The radical scavenging activity was expressed as percentage of inhibition according to the following formula[15]:

$$Inhibition(\%)=\left[\frac{(A_{control}-A_{sample})}{A_{control}}\right]\times 100(\%)$$

Control (0.2 mL of DPPH + 3.8 mL methanol), IC_{50} (the concentration of extract in mg/mL needed to scavenge 50% of the DPPH radical) was calculated from their concentration-response curve.

2.2.6 Trained sensory evaluation (Descriptive analysis)

A seven-member trained descriptive panel, who consumed olive oil at least once per week to be accustomed to eating olive oil, was trained according to the Spectrum methodology. The Spectrum method involves scoring perceived intensities with reference to pre-learned scales using standard attribute names with their standards that define a scale of intensity[16]. Four 3-hour orientation sessions were organized for the panel to get familiarized with the test methodology necessary to describe the characteristics of sensory attributes of olive oil samples. The panelists used the orientation session to improve their reproducibility and accuracy.

The treatments were evaluated for the following attributes: Color just about right scale (JAR): 1= too much yellow, 2= too light yellow, 3= just about right, 4= too green, 5= too much green; Astringent taste JAR: 1= too much astringent, 2= too light astringent, 3= just about right, 4= not too astringent, 5= not too much astringent; Rancid flavor JAR: 1= too much rancid, 2= too rancid, 3= just about right, 4= not too rancid , 5= not too much rancid; Rancid odor JAR: 1= too much rancid, 2= too rancid, 3= just about right, 4= not too rancid, 5= not too much rancid. A 15-point intensity scale anchored by references as defined by the Spectrum methodology was used in assigning values to each descriptor. Trained panelists evaluated the olive oil samples at 0, 15, 30, 45, and 60 days.

2.3 Statistical analysis

Data were analyzed using the general linear model (GLM) procedure with SAS Version 8.2 software package (SAS 2002 Institute Inc., Cary, NC, USA)[17]. Means were separated by LSD analysis ($p\leq 0.05$).

3 Results and discussion

3.1 Acidity

The acidity values of olive oil stored in containers made from three types of packaging materials (plastic, glass, and tinplate) during 60 days are shown in Table 1.

As expected, an increase in acidity as time increased from 0 to 60 days can be observed in all type of storage containers, which was in agreement with the observations of Agar et al.[18] and Yildirim[19]. The acidity increase could be due to the development of rancidity as the result of free fatty acid hydrolysis[19,20] .

When comparing the increase of the acidity values with respect to the type of bottle materials, the olive oil samples stored in the tinplate container exhibited the highest increase in acidity during 60 days of storage (1.25% to 2.51%), while the lowest increase was observed for samples in the glass container (1.25% to 1.53%). The plastic container had the intermediate acidity value. The differences in acidity changes in oil packaged with different materials should be caused by the interactions between the packaging material and the food product, especially for tinplate packaging[18,21,22]. The higher quality degradation for tinplate-packaged product (Table 1) was in agreement with that reported by Hung and Zhou[23], who observed the rapid decline of corrosion resistance of tinplate and the consequent pitting corrosion of tinplate, which may be responsible for the fast quality changes of the product in the package.

3.2 Peroxide values (PV)

The PV values of olive oil stored with three types of packaging (plastic, glass, and tinplate) during 60 days are shown in Table 1. At day 0, the lowest PV value was recorded (6.13 meq/kg) in both plastic and glass containers, and this value increased during storage time. A similar trend in PV value changes was observed by Yildirim[19], Ardo[24], and Mailer and Graham[25]. Among all storage containers the lowest increased in PV was in glass bottle (7.17 meq/kg), which could be linked to the good oxygen barrier property and chemical inactivity of glass[2,18,26]. The highest value was 10.21 meq/kg during storage in tinplate material (Table 1). The PV value changes in this study fell in the range of 6 to 14 meq/kg reported by Gutierrez- Rosales et al.[27] and Cinquanta et al.[28]. The results also (Table 1) showed that glass containers gave the least in PV, which agreed with Kucuk and Cancer[26] who studied the effect of container materials and storage time on the quality of sunflower oil. Similar to the acidity changes, storage oil in plastic container after 60 days had an intermediate increase in PV.

3.3 Total phenolics and antioxidant activities (antiradical)

The total phenolics and antioxidant activities of the oil during storage are shown in Table 1. At the beginning storage time, olive oil contained 20.22 mg/100 mg total phenolic compounds, and this value was in consistent with the data (121 – 410 mg/kg) reported by Cinquanta et al.[28]. Afterwards, the total content of phenols decreased as a function of time, with various degree of reduction among the storage containers. The highest phenols content reduction was recorded in the tinplate container (15.10 mg/100 mg). For both the plastic and glass containers, the concentrations of phenols during storage reduced less pronouncedly compared to that in the tinplate container, which is in agreement with that reported by Mailer and Graham[25]. All phenolic compounds reached their lowest values at the end of 60-day storage. The reduction in total phenolics of the oil is a result of oxidation and hydrolytic activities, which increased during storage[19]. The decrease in antioxidant activities could be caused by hydrolysis that leading to increase in tyrosol and 5-hydroxytyrosol[29]. Consequently, increased levels of free radicals, resulting from oxidation, will increase the rate at which the antioxidants are utilized and reduce their effectiveness[25,28,30,31].

Results in Table 1 showed that the lowest range between the initial and final antiradical activity was at glass bottle, then both plastic and tinplate (0.028 and 0.026, respectively) offered the same level in their low ability to keep the quality of olive oil through maintained its activity to scavenge the free radicals, which agreed with Kucuk and Cancer[26]. In the study of Gutierrez-Rosales et al.[27] of the content of antioxidant in olive oil by measured the reduction in the concentration (1 ppm= 1 μmol/mol) of β- carotene with time, they showed that at 0 day the initial concentration was 2.31 ppm, and after one month of storage olive oil the concentration decreased to 1.28 ppm, then at the end of storage time (two months) the final concentration of β-carotene was 1.46 ppm; which means as time increased from 0 to

60 days the total phenolics and antioxidant activities decreased and this could be due to oil oxidation during storage[19,20,32]. In addition, glass and plastic containers slightly kept more than phenolics and antioxidant compounds the tinplate contain, which agreed with that reported by Sharma and Sharma[20] where olive oils of different cultivars exhibited insignificant increase in their total phenols during storage at ambient condition in glass bottles.

The results obtained in Table 1 of tinplate were in agreement with what was reported by Yildirim[19]; free radical formed from the decomposition of hydroperoxides can elevate further oxidation, which causes earlier than expected off-flavor formation and results in lower oil stability during storage. The effect of oxygen concentration on the oxidation of oil was increased in the presence of metals. The reduction of antioxidants in plastic containers could be due to the migration of active compounds between oil and packaging material as reported by Tawfik[33], who measured the amount of olive oil absorbed by different types of packaging material stored in plastic material and the migration increased with extending storage time during 60 days.

3.4 Sedimentation

Sedimentation of olive oil stored at three types of packaging containers during 60 days is shown in Table 1. The sedimentation value increased with the storage time for all type of containers only after 60 days of storage, similar to what reported by Kanavouras et al.[34]. The best container was glass bottle, which had the lowest sedimentation value (0.13%). Tinplate had the highest sedimentation percent (0.17%), which means that it had the highest impact on the change of quality of stored olive oil during the storage.

Table 1 Acidity, peroxide value, total phenolics, antioxidant activities (antiradical) and sedimentation of olive oil filled in three types of packaging during 60 days of storage

Container type	Storage period/d	Acidity/%	Peroxide value/meq · kg^{-1}	Total phenols/mg · (100 mg)$^{-1}$	Antiradical (1/IC50)	Sedimentaion/%
Plastic	0	1.25f	6.13j	20.22a	0.082a	—
	15	1.27f	6.61f	19.50ab	0.061b	—
	30	1.34ef	7.34de	18.10ab	0.045e	—
	45	1.54d	7.43de	17.75ab	0.038g	—
	60	1.79c	7.71d	17.15b	0.028i	0.14bc
Glass	0	1.25f	6.13j	20.22a	0.082a	—
	15	1.27f	6.41fj	20.15a	0.058b	—
	30	1.29f	6.72ef	18.40ab	0.046d	—
	45	1.45de	7.14e	17.75ab	0.040f	—
	60	1.53d	7.17e	16.95b	0.037h	0.13c
Tinplate	0	1.25f	6.22j	20.22a	0.082a	—
	15	1.32ef	7.14e	18.80ab	0.051c	—
	30	1.56d	8.12cd	17.75ab	0.040f	—
	45	1.94b	9.30b	16.87b	0.038g	—
	60	2.51a*	10.21a	15.10c	0.026j	0.17ab

Note: 1 All values are on a dry basis. The values are the means of three determinations. * Column values with the same letters were not significantly different (p<0.05).

3.5 Descriptive sensory analysis

The descriptive sensory analysis of olive oil stored at three types of packaging materials (tinplate, plastic, and glass) during storage is shown in Table 2. It can be seen from Table 2 that for samples in the tinplate container the most significant changes in physical properties can be observed, showing the negative impact on the quality of olive oil. The glass container had the lowest changes sensory values (Table 2). Obviously, the glass container was the best material among the three packaging materials, followed by plastic bottle. Yildirim[19] and Kiritsakis et al.[21] also reported that glass container had the highest values of color, taste, flavor, and odor retention followed by plastic and tinplate containers, respectively. The reduction of sensory attributes especially in tinplate container could be due to the reaction of other components of olive oil such as phenolic compounds with tinplate that negatively affected descriptive attributes. In addition, the physical characteristics of the packaging material may also affect the final quality of the oil, depending on the extent of the deteriorative interactions[2].

Table 2 Descriptive sensory analysis of olive oil filled in three types of packaging during 60 days of storage

Container type	Storage period/d	Sensory attributes JAR (Just About Right Scale)			
		Color	Astringent taste	Rancid flavor	Rancid odor
Tinplate	0	4.5a*	4.6a	4.7a	4.6a
	15	4.4ab	4.5ab	4.5ab	4.5ab
	30	3.9c	4.2cd	4.3bc	4.4abc
	45	3.5de	3.8e	4.2c	4.1de
	60	3.2e	3.5f	3.4e	3.6f
Plastic	0	4.5a	4.6a	4.7a	4.6a
	15	4.4ab	4.5ab	4.6ab	4.6a
	30	4.2b	4.3bcd	4.5ab	4.5ab
	45	4.0c	4.2cd	4.3bc	4.4abc
	60	3.6d	4.0e	3.9d	3.9de
Glass	0	4.5a	4.6a	4.7ab	4.6a
	15	4.3a	4.5ab	4.6ab	4.6a
	30	4.3a	4.4abc	4.5ab	4.5ab
	45	4.2b	4.cbcd	4.4bc	4.5ab
	60	3.9c	4.3bcd	4.4bc	4.3bc

Note: 1 All values are on a dry basis. The values are the means of three determinations.

* Row values with the same letters were not significantly different (p<0.05).

The observed color changes increased with the storage time probably as a consequence of the reduction in the pigment content. These compounds correlate with the shelf life of oil and, in particular, its resistance to oxidation[19]. The green color of olive oil faded off as the oil ages, which might be caused by conversion of chlorophyll to alternative yellow and brown pigments, i.e. pheophytins (PP) and pyropheophytins (PPP)[25]. The rancid flavor development in olive oil could be due to, as reported by Kanavouras et al.[2] oxidation, the decomposition of the hydroperoxides formed and the consequent formation of newly generated volatile compounds. The volatile aldehydes and vinyl ketones are known to be mainly responsible for potent off-flavors, because their odor threshold levels are very low. Ardo[24] demonstrated that as free fatty acids increased undesirable sensory properties occurred. Bendini et al.[32] and Kalua et al.[35] demonstrated that the negative sensory attributes in olive oil can be associated with volatile compounds, which are mainly formed by chemical oxidation.

4 Conclusions

The acidity values of olive oil significantly increased during a 60-day storage at room temperature. The olive oil placed in the glass container had the lowest acidity and PV values followed by those in the plastic and tinplate containers. As time increased from 0 to 60 days the total phenolics and antioxidant activities decreased, which could be caused by oil oxidation during storage. In addition, the oil in the glass and plastic containers slightly kept more phenolics and antioxidant compounds than that in the tinplate container. The tinplate container had higher sedimentation amounts than the other two containers. The descriptive analysis indicated that as time increased from 0 to 60 days the quality attribute values decreased. The olive oil in the glass container had the highest values of color, taste, flavor, and odor followed by those in the plastic and tinplate containers. The reduction of sensory attributes especially in the tinplate container could be due to the reaction of other components in olive oil such as phenolic compounds with tinplate that negatively affected the descriptive attributes.

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