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Research Article

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Physical Characteristic Changes of Syrian Olive (*Olea Europaea*) Oils During Irradiation and Storage Time

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Abstract

There is no information available in the literature on the effect of gamma irradiation on the physical properties of olive oils. Therefore, the objective of this study was to determine the effect of γ-irradiation treatment (0, 1, 2 and 3 kGy), storage time of olives (0, 30 and 45 days), and storage time of extracted oils (0, 6 and 12 months) on physical properties of Syrian Kaissy cv olive oil (SKOO). Refractive index (RI), viscosity and color of olive oils were determined, immediately after extraction and after 6 and 12 months of storage. Results showed that the RI (1.4659 ± 0.0002), viscosity (151.67 ± 1.53 mPa s^{-1}), and color parameters (lightness (L*) (71.51 ± 2.06), redness (a*) (14.65 ± 0.91), yellowness (b*) (56.85 ± 3.27) and overall color difference (ΔE) (53.74 ± 3.97) values of olive oil was significantly ($p<0.05$) changed by γ-irradiation and storage time. In general, the RI of SKOO was significantly ($p<0.05$) increased by γ-irradiation and decreased by extended storage time. The viscosity values of SKOO were significantly ($p<0.05$) decreased by γ-irradiation and storage time. Irradiation treatment and storage time increased significantly ($p<0.05$) the a* and ΔE values, and decreased significantly ($p<0.05$) the b* of olive oils. The analytical parameters studied of oil extracted from irradiated and non-irradiated fruits were within the limits established by the International Olive Council (IOC, 2015).

Keywords

Olive oil, Viscosity, Refractive index, Color, γ-irradiation

Introduction

Olive oil (OO), represents a very popular food commodity, not only for its delicious flavor, but also for its health- promoting potential provided by polyunsaturated fatty acids and other compounds, such as phenolic and oleic acid [1, 2]. The beneficial health properties of olive oil have been known for centuries, particularly in Mediterranean region [3, 4]. A number of studies have already been indicated that the incidence of different types of cancer in the Mediterranean basin is lower compared to other regions [5].

Clear standards and regulars are useful in that they provide the claims with the best feasible oil, diminish the opportunity for fraud, and reward producers who are vigilant in the production of their olive oil [6]. However, both its commercial classification and genuineness evaluation remain legally defined by trade standards compiled in the Codex Alimentarius Norms [7], and the International Olive Council (IOC) Trade Standards [8]. The latter are recognized by most of the olive oil producers and marketers all over the world, since they are drawn up and updated based on IOC olive oil records and databases of the countries that are members of this council, which are the major suppliers of olive oil in the global market [9].

Currently, most efforts have focused on understanding the differences in oil quality from olive fruits of different qualities and in the reduction of quality deterioration once the oil is produced [10]. Post-harvest storage of olives has been shown to increase the deterioration of the olive oil [11]. Olive oil quality depends on market preference and is based open consumer perceptions of aroma, taste and color, which may change over time and with location [12].

Irradiation has become an effective means of processing and preserving food products [13]. A Joint FAO/IAEA/WHO Expert Committee on the Wholesomeness of Irradiation of Food has ruled that foods subjected to low dosage (up to 10 kGy) of irradiation are safe and do not require toxicology testing [14]. The effect of irradiation on locally stored foods is of utmost importance and an insight into these aspects of storage will help in understanding the shelf life of foods as well as its effects on sensitive nutrients [15]. Ionizing radiation has very high energy and leads to some changes in the structure of the organisms and modification of the biological and physiological processes that occur in organ tissues [13, 16, 17].

Further investigation should be made in post-harvest fruit handling technologies that enhance the generation of positive compound and characteristics. Therefore, the objectives of the present study were to characterize the physical properties of the olive oils produced in Syria, and to determine the effect of γ-irradiation treatment (0, 1, 2 and 3 kGy), storage time of olives (0, 30 and 45 days), and storage time of extracted oils (0, 6 and 12 months) on physical properties of Syrian Kaissy cv olive oil (SKOO).

Materials and Method

Material

Samples of olives of good quality and in the mature firm condition (Kaissy cultivar that the most widespread in Syria) were harvested from the trees grown in grove located at Deer Al Hajar research station, southeast Damascus, Syria (33° 21´ N, 36° 28´ E) at 617 m above sea level during 2009//2010 growing season. Olive fruits were weighed as in the sampling plan and transferred into polyethylene bags for irradiation. The sample size was considered reasonably well enough for the purpose of the study. Each bag of olives (1 kg) was considered as a replicate.

Treatments and analysis performed

Olive fruits were irradiated with 0, 1, 2 and 3 kGy, at room temperature and atmospheric pressure, using as γ-irradiated ^{60}CO (ROBO, Techsnabexport, Moscow, Russia). The irradiation was carried out in the stationary mode of operation with the possibility of varying dose rate (10.846 to 3.921 kGy h^{-1}) depending on the location and the distance from the source (10 to 40 cm). The samples were irradiated at place (15 cm from source) with a dose rate of 9.571 kGy h^{-1}. The absorbed dose was determined using alcoholic chlorobenzene dosimeter [16].

Oil extraction

The oils from control and irradiated olive fruits were extracted from olives stored at ambient temperature for 0, 30 and 45 days after irradiation using a mechanical and physical processes [18]. Olive fruits were crushed with hummer crusher and slowly mixed for about 30 min at 27 °C, Then, the past mixed was centrifuged at 3000 rpm for 3 min without addition of water to extract the oil. Finally, the oils were decanted and immediately transferred into dark glass bottles and stored at room temperature (20-25 °C) for the irradiation treatment and physic-chemical properties. Chemical analysis of oils extracted from irradiated and non-irradiated olive fruit samples were performed immediately after irradiation, and after 6 and 12 months of storage.

Chemical and physical analysis of oils

The refractive index (RI) of olive oil samples was measured in daylight with an Abbe refractometer (VED Carl Zeiss JENA, German) calibrated against pure water at 25 °C. The viscosity of the oils was measured with HAAKE viscometer 6 R plus Model (RTM) using a R2 column at 200 rpm. Viscosity values were determined and expressed as mPa s^{-1}. The color of olive oil was measured using AvaSpec Spectrometer Version 1, 2 June 2003 (Avantes, Holland) and expressed as color L* (lightness), a* (redness), b* (yellowness) values and overall color difference (ΔE). Reflectance values were obtained at wave length of 568 nm by exposing the samples to the illuminant [19]. However, the reported results (L*, a*, b*) are the mean of 9 determination.

Statistical analysis

The four treatments were distributed in a completely randomized design with three replicates. Data were subjected to the analysis of variance test (ANOVA) using the SUPERANOVA computer package (Abacus Concepts Inc., Berkeley, CA, USA; 1998). The p value of less than 0.05 was considered statistically. The degree of significance was denoted as: $p<0.05^*$, $p<0.01^{**}$ [20].

Results and Discussion

Effect of γ-irradiation and storage period on refractive index of olive oil

Refractive index (RI) is the measure of the thickness as well as purity or clarity of the oil [21, 22]. Table 1, shows the variation of the index of refraction with irradiation dos and storage time of olive oil obtained from Syrian Kaissy cv olive fruits (SKOF) treated at 0, 1, 2 and 3 kGy of γ-irradiation and stored for 0, 30 and 45 days before extraction and stored oil at ambient temperature for 0, 6 and 12 months after extraction. The initial RI for SKOO obtained from fruits stored at ambient temperature for 0, 30 and 45 days were 1.4659, 1.4640 and 1.4679, respectively. These values falls within the recommended codex values for olive oils (1.4677-1.4705) [7]. The refractive index of SKOO of 1.4659 showed that it is not as thick as most drying oil whose refractive indices fell between 1.475 and 1.485 [21]. However, significant

Table 1: Effects of γ-irradiation and storage period on refractive index (nD 25 °C) physical properties of olive oil.

Treatments		Control	1 KGY	2 KGY	3 KGY	P-Value
Storage periods		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
0 days	0 months	1.466 ± 0.0002^{aA}	1.466 ± 0.0002^{aA}	1.466 ± 0.0002^{aA}	1.466 ± 0.0002^{aA}	**0.0011**
	6 months	1.466 ± 0.0002^{aB}	1.466 ± 0.0002^{aB}	1.457 ± 0.0002^{aB}	1.466 ± 0.0002^{aB}	**0.2192**
	12 months	1.464 ± 0.0001^{aC}	1.464 ± 0.0001^{aC}	1.465 ± 0.0001^{aC}	1.464 ± 0.0001^{aA}	**0.0083**
	P-Value	**0.0001**	**0.0001**	**0.0001**	**0.0001**	
30 days	0 months	1.464 ± 0.0001^{aA}	1.464 ± 0.0001^{aA}	1.464 ± 0.0001^{aA}	1.464 ± 0.0001^{aA}	**0.0001**
	6 months	1.463 ± 0.0003^{aB}	1.463 ± 0.0003^{aB}	1.463 ± 0.0003^{aA}	1.464 ± 0.0003^{aB}	**0.0001**
	12 months	1.462 ± 0.0001^{aC}	1.462 ± 0.0001^{aA}	1.462 ± 0.0001^{aA}	1.462 ± 0.0001^{aC}	**0.0440**
	P-Value	**0.0001**	**0.0001**	**0.0001**	**0.0001**	
45 days	0 months	1.468 ± 0.0003^{aA}	1.467 ± 0.0003^{aA}	1.467 ± 0.0003^{aA}	1.466 ± 0.0003^{aA}	**0.0001**
	6 months	1.467 ± 0.0001^{aB}	1.466 ± 0.0001^{aB}	1.466 ± 0.0001^{aB}	1.466 ± 0.0001^{aB}	**0.0006**
	12 months	1.465 ± 0.0002^{aC}	1.465 ± 0.0002^{aC}	1.466 ± 0.0002^{aC}	1.465 ± 0.0002^{aC}	**0.0113**
	P-Value	**0.0001**	**0.0001**	**0.0001**	**0.0001**	

^{abc} Means values in the same column not sharing a superscript are significantly different.

^{ABC} Means values in the same row not sharing a superscript are significantly different.

NS: not significant.

* Significant at p<0.05.

** Significant at p<0.01.

N= 3 replicates for each treatments.

interactions between location, harvest date and crop year were found regarding the characteristics of olive fruits [23]. Results in Table 1 indicate that used doses of γ-irradiation had a significant (p<0.01, except for oil samples extracted from olive immediately after harvest and stored for 6 months) effect in RI of SKOO obtained from olives stored at ambient temperature for 0, 30 and 45 days. The RI of all oil samples (extracted from olives stored at ambient temperature for 0, 30 and 45 days), and treated with 0, 1, 2 and 3 kGy of γ-irradiation significantly (p<0.01) dropped during the storage time. All of the samples had RI values between 1.4620 and 1.2679 at 25 °C. It is quite expected a physical constant be within the ranges, as long as there is no purity change the sample [24]. Refractive index of γ-irradiated groundnut oil were not significantly affected [25]. Dughaish [26] reported that γ-irradiation caused some change in olive oil structure, which caused the observed change in the physical properties of the oil. From his study he concluded that olive and corn oils were the most sensitive to γ-irradiation, while sunflower, black seed and palm are less sensitive to γ-irradiation. The RI value depend on degradation and percentage of polar compounds formed during oxidation and hydrolytic reactions [27]. The refractive value in oils increased due to the unsaturated components formed by γ-irradiation in oils [26].

Effect of γ-irradiation and storage period on viscosity of olive oil

Viscosity is a measure of resistance of fluid to deform under shear stress, it commonly perceived as thickness, or resistance to pouring. The absolute viscosity value of the liquid is an important property needed in fluid flow and heat transfer unit operations [28]. The viscosity in term of percent of mPa s^{-1} of SKOO obtained from olives treated at 0, 1, 2 and 3 kGy of γ-irradiation and stored at ambient temperature for 0, 30 and 45 days before extraction and stored at ambient temperature for 0, 6 and 12 months after extraction were presented in Table 2. The initial values of viscosity for SKOO obtained from fruits stored at ambient temperature for 0, 30 and 45 days were 151.67, 155.00 and 152. 67, respectively. The viscosity value of SKOO was significantly (p<0.05) decreased by storage time. The viscosity values of virgin olive oils from three olive varieties growing in Turkey changed between 55.775 and 62.175 mPa s^{-1}[29].

As shown in Table 2, viscosity of SKOO extracted immediately after the harvesting decreased as the used irradiation doses increased. In fact, the viscosity decreased (p<0.01) from 151.67 mPa s^{-1} for control samples to 146.67 mPa s^{-1} for samples treated with 3 kGy. While the viscosity of the SKOO obtained from olives stored at ambient temperature for 30 and 45 days were increased (p<0.01) as the used irradiation doses increased. The viscosity of the SKOO obtained from olives stored at ambient temperature for 30 days were 155.00, 157.67, 160.00 and 161.00 mPa s^{-1}, whereas the viscosity of the SKOO obtained from olives stored at ambient temperature for 45 days were 152.67, 157.00, 157.67 and 167.00 mPa s^{-1} for samples treated with 0, 1, 2 and 3 kGy respectively. Our results indicate that the difference in the viscosity between irradiated and non-irradiated SKOO may be attributed to the degradation of some high molecular weight components, and changing these components from non-soluble to soluble ones in the test oils. However, γ-irradiation caused molecular changes resulting destruction the polysaccharides, they would likely be changed of some important properties of the polymers. Lowering the molecular structure of the polysaccharide can be achieved by various methods including ionizing irradiation [30, 31]. The effect of γ-irradiation on the viscosity of olive oil

Table 2: Effects of γ-irradiation and storage period on viscosity (mPa s^{-1}) refractive of olive oil.

Treatments		Control	1 KGY	2 KGY	3 KGY	P-Value
Storage periods		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
0 days	0 months	151.7 ± 1.5^{aB}	150.0 ± 1.7^{abA}	147.7 ± 1.5^{bcB}	146.7 ± 0.6^{cC}	0.0097
	6 months	149.7 ± 0.6^{aB}	149.7 ± 0.6^{aA}	148.7 ± 0.6^{abB}	147.7 ± 0.6^{bB}	0.0079
	12 months	147.7 ± 3.4^{aA}	148.0 ± 4.7^{aA}	149.7 ± 1.2^{bA}	149.0 ± 0.6^{abA}	0.1741
	P-Value	0.0156	0.1190	0.1866	0.0027	
30 days	0 months	155.0 ± 1.0^{cA}	157.7 ± 0.6^{bA}	160.0 ± 1.0^{aA}	161.0 ± 0.0^{aA}	0.0001
	6 months	130.0 ± 0.0^{cC}	130.7 ± 0.6^{cC}	131.7 ± 0.6^{bC}	133.0 ± 0.0^{aC}	0.0001
	12 months	148.0 ± 1.0^{aB}	148.0 ± 1.0^{aB}	149.0 ± 1.0^{aB}	149.3 ± 0.6^{aB}	0.2437
	P-Value	0.0001	0.0001	0.0001	0.0001	
45 days	0 months	152.7 ± 2.5^{cA}	157.0 ± 1.0^{bA}	157.7 ± 0.6^{bA}	167.0 ± 0.0^{aA}	0.0001
	6 months	122.3 ± 0.6^{aB}	121.3 ± 0.6^{bC}	122.0 ± 0.0^{abC}	122.7 ± 0.6^{aC}	0.0553
	12 months	151.3 ± 0.6^{cA}	152.0 ± 0.0^{cB}	154.7 ± 1.5^{bB}	156.7 ± 0.6^{aB}	0.0002
	P-Value	0.0001	0.0001	0.0001	0.0001	

abc Means values in the same column not sharing a superscript are significantly different.
ABC Means values in the same row not sharing a superscript are significantly different.
NS: not significant.
* Significant at p<0.05.
** Significant at p<0.01.
N= 3 replicates for each treatments.

has not been investigated. Therefore, we compared the results of this study with that performed for other products. Our suggestion is in agreement with those of [32], who reported a dramatic decrease in the dispersion viscosity of heat gelatinized suspension of several irradiated spices with the starch content compared with that of un-irradiated samples. The effect of irradiation seems to be related to the radio-depolymerization of starch in irradiated spices [33]. The previous studies in our lab indicated that, using 5, 10, 15, and 20 kGy doses of γ-irradiation decreased the viscosity value of licorice extracts as compared with control samples [17].

Effect of γ-irradiation and storage period on color parameters of olive oil

The color of olive oil samples was evaluated from the chromatic coordinates a* corresponding to the green zone, b* corresponding to the yellow zone, Lightness L*, and ΔE values of the absorption spectrum. The color in term of L*, a*, b* and ΔE values of oils obtained from SKOF treated at 0, 1, 2 and 3 kGy of γ-irradiation and stored at ambient temperature for 0, 30 and 45 days before extraction and stored at ambient temperature for 0, 6 and 12 months after extraction were presented in Table 3 and 4.

Lightness (L*). As showed in Table 3, the initial L* values of SKOO obtained from fruits stored at ambient temperature for 0, 30 and 45 days were 71.51, 50.83 and 72.24, respectively. The lightness L* value of SKOO was significantly (p<0.01) changed by γ-irradiation and storage time. Gamma irradiation doses of 1 and 2 kGy decreases significantly (p<0.05) the L* value of oil obtained from SKOF immediately after harvest. While, 1 and 3 kGy increased significantly (p<0.05) the L* value of oil obtained from SKOF stored at ambient temperature for 45 days. However, after 12 months of storage, the L* value of oil extracted from olives immediately after harvest were significantly lower (p<0.05), while the L* value of oil extracted from SKOF stored at ambient temperature for 30 and 45 days were significantly higher (p<0.05) than those of control samples (at month zero of storage).

Redness/greenish (a*) value. As showed in Table 3, the initial a* values of oil obtained from SKOF stored at ambient temperature for 0, 30 and 45 days were 14.65, 11.08 and 24.87, respectively. The greenish a* value of olive oil was significantly (p<0.01) changed by γ-irradiation and storage time. In general, γ-irradiation and storage time increased significantly (p<0.05) the a* value of SKOO.

Yellowness (b* value). As showed in Table 4, the initial b* values of oil obtained from SKOF stored at ambient temperature for 0, 30 and 45 days were 56.85, 56.24 and 41.42, respectively. The yellowness (b* value) of SKOO was significantly (p<0.01) changed by γ-irradiation and storage time. In general, γ-irradiation and storage time decreased significantly (p<0.01) the b* value of SKOO.

Color difference (ΔE value). As showed in Table 4, the initial ΔE values of oil obtained from SKOF stored at ambient temperature for 0, 30 and 45 days were 53.74, 66.75 and 69.43, respectively. The color difference (ΔE value) of SKOO was significantly (p<0.01) changed by γ-irradiation and storage time. In general, γ-irradiation increased significantly (p>0.01) the ΔE of SKOO.

Olive oil color is the results of green and yellow hues due to the presence of color pigments such as chlorophylls and carotenoids. It is influenced by olive cultivar, maturation index, production zone, extraction system, and storage condition. Therefore, the color value is considered as a quality index for its measurement [34].

The used olive oil showed high a* and b* values, suggested

Table 3: The effects of γ-irradiation and storage period on color change (L- value (lightness) and a- values (redness)) of olive oil.

Treatments		Control	1 KGY	2 KGY	3 KGY	P-Value
				L		
Storage periods		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
0 days	0 months	71.5 ± 2.1^{aC}	66.1 ± 1.3^{bC}	67.0 ± 0.2^{bC}	71.8 ± 0.4^{aC}	**0.0007**
	6 months	82.8 ± 0.1^{aA}	73.2 ± 0.3^{bA}	72.9 ± 0.1^{bA}	73.2 ± 0.1^{bA}	**0.0001**
	12 months	66.0 ± 0.4^{cbB}	68.3 ± 0.0^{bB}	65.2 ± 0.6^{dB}	69.1 ± 0.1^{aB}	**0.0001**
	P-Value	**0.0001**	**0.0001**	**0.0001**	**0.0001**	
30 days	0 months	50.8 ± 0.1^{aC}	51.8 ± 0.7^{aC}	51.5 ± 1.9^{aC}	52.0 ± 0.3^{aC}	**0.5782**
	6 months	71.4 ± 0.1^{aA}	70.6 ± 0.1^{bB}	69.8 ± 0.1^{cB}	66.8 ± 0.2^{dB}	**0.0001**
	12 months	84.9 ± 0.0^{cB}	85.2 ± 0.1^{bA}	84.3 ± 0.2^{dA}	93.9 ± 0.2^{aA}	**0.0001**
	P-Value	**0.0001**	**0.0001**	**0.0001**	**0.0001**	
45 days	0 months	72.2 ± 0.5^{cC}	74.7 ± 0.3^{bA}	73.6 ± 1.3^{bcC}	77.0 ± 1.0^{aC}	**0.0010**
	6 months	69.1 ± 0.1^{bB}	69.4 ± 1.4^{bB}	71.2 ± 0.0^{aB}	71.8 ± 0.6^{aB}	**0.0048**
	12 months	89.1 ± 0.6^{bA}	90.6 ± 0.5^{aA}	88.5 ± 0.9^{bA}	91.4 ± 0.1^{aA}	**0.0010**
	P-Value	**0.0001**	**0.0001**	**0.0001**	**0.0001**	
				a		
0 days	0 months	14.7 ± 0.9^{bcC}	12.0 ± 0.6^{cC}	17.0 ± 1.6^{abB}	17.9 ± 2.7^{aB}	**0.0097**
	6 months	29.5 ± 0.0^{aA}	28.5 ± 0.1^{cB}	28.9 ± 0.1^{bA}	29.5 ± 0.0^{aA}	**0.0001**
	12 months	25.1 ± 0.3^{cB}	27.9 ± 0.1^{bB}	28.8 ± 0.3^{aA}	28.5 ± 0.1^{aA}	**0.0001**
	P-Value	**0.0001**	**0.0001**	**0.0001**	**0.0002**	
30 days	0 months	11.1 ± 0.1^{bC}	12.5 ± 0.2^{aA}	12.3 ± 0.2^{aC}	11.4 ± 0.5^{bC}	**0.0013**
	6 months	28.3 ± 0.1^{cB}	30.5 ± 0.0^{aB}	30.1 ± 0.0^{bB}	30.0 ± 0.1^{bB}	**0.0001**
	12 months	52.1 ± 1.4^{bA}	55.5 ± 0.3^{aA}	53.7 ± 0.1^{cA}	60.3 ± 0.2^{aA}	**0.0001**
	P-Value	**0.0001**	**0.0001**	**0.0001**	**0.0001**	
45 days	0 months	24.9 ± 0.3^{bC}	27.2 ± 0.2^{aC}	27.1 ± 0.4^{aC}	26.6 ± 0.9^{aC}	**0.0016**
	6 months	30.2 ± 0.1^{cB}	32.0 ± 0.1^{bB}	32.9 ± 0.1^{aB}	$32.9. \pm 0.1^{aB}$	**0.0001**
	12 months	57.7 ± 0.5^{bA}	59.7 ± 1.3^{aA}	56.5 ± 0.2^{bcA}	55.2 ± 0.4^{cA}	**0.0004**
	P-Value	**0.0001**	**0.0001**	**0.0001**	**0.0001**	

^{abc} Means values in the same column not sharing a superscript are significantly different.

^{ABC} Means values in the same row not sharing a superscript are significantly different.

NS: not significant.

* Significant at p<0.05.

N= 3 replicates for each treatments.

that the virgin olive oil contain high amount of chlorophyll and carotenoid mass fractions. This is probably the consequence of the harvest at the earlier stage of ripeness. It is known that with increased ripening, the values of these ordinates decrease similarly to those of pigment mass fraction, which is in agreement with the loss of color intensity in the corresponding oils [35].

There is no information available in the literature on the effect of gamma irradiation on the Hunter's color values of olive oils. However, for other plant materials, and in studying the effect of γ-irradiation treatment on the oil seeds or nuts. Al-Bachir [15] reported that irradiation doses of 1, 2 and 3 kGy had significant effect (p<0.05) on color values (L*, a* and b*) of pistachio oil. Some color change on almond oils due to irradiation was found in almonds oil samples at time zero and after 12 months of storage [36]. Gölge and Ova [37] reported statistically significant change in L* and b* values for pine nuts at doses between 0.5 and 5 kGy. Mexis and Kontominas [38] reported a statistically significant change in a* values for cashew nuts at doses 1.0, 1.5 and 3 kGy. Mexis et al. [39] reported a decreased in L* parameter (p<0.05) at dose > 3 kGy, while color parameters a* and b* remained unaffected after irradiation of almonds kernels at doses up to 7 kGy. Irradiation affected the colors of the brush by reducing its brightness and increasing redness and yellowness of the herbal cosmetic products [40]. Irradiation reduced L*, a* and b* values reflecting that the oil became darker or less light. Such darkening in color may be associated with (a) change in properties of proteins through cross linking when they react with hydro-peroxides and their degradation products which is manifested as browning, and (b) non enzymatic lipid-protein interaction causing browning [37]. Cecchi et al. [41] reported that carotenes and chlorophylls contents in virgin olive oil decreased with increasing storage time.

Table 4: The effects of γ-irradiation and storage period on color change (b- value (yellowness) and ΔE values (overall changes)) of olive oil.

Treatments		Control	1 KGY	2 KGY	3 KGY	P-Value
			b			
Storage periods		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
0 days	0 months	56.9 ± 3.3^{bA}	65.7 ± 2.0^{aA}	48.3 ± 3.6^{cA}	49.0 ± 5.5^{cA}	**0.0001**
	6 months	46.5 ± 0.3^{aB}	42.7 ± 0.4^{cB}	44.4 ± 0.0^{bA}	40.9 ± 0.2^{dB}	**0.0001**
	12 months	38.7 ± 0.2^{bC}	40.4 ± 0.2^{aB}	35.2 ± 0.4^{cB}	38.7 ± 0.2^{bB}	**0.0001**
	P-Value	**0.0001**	**0.0001**	**0.0006**	**0.0181**	
30 days	0 months	56.2 ± 0.2^{aA}	46.6 ± 1.7^{cA}	46.3 ± 2.7^{cB}	51.4 ± 2.3^{bB}	**0.0008**
	6 months	44.2 ± 0.2^{aB}	40.9 ± 0.5^{dB}	40.0 ± 0.0^{cC}	43.4 ± 0.2^{dC}	**0.0001**
	12 months	39.7 ± 1.4^{cC}	31.9 ± 0.5^{dC}	35.5 ± 0.5^{bA}	32.2 ± 0.1^{aA}	**0.0001**
	P-Value	**0.0001**	**0.0001**	**0.0005**	**0.0001**	
45 days	0 months	41.4 ± 0.4^{aB}	35.1 ± 2.6^{bAB}	39.2 ± 1.6^{aA}	38.4 ± 1.7^{aB}	**0.0138**
	6 months	42.7 ± 0.3^{bA}	36.4 ± 0.2^{dA}	38.7 ± 0.1^{cA}	43.7 ± 0.3^{aA}	**0.0001**
	12 months	34.8 ± 0.1^{cC}	32.3 ± 2.3^{dB}	37.8 ± 0.4^{bA}	42.4 ± 0.6^{aA}	**0.0001**
	P-Value	**0.0001**	**0.1141**	**0.2711**	**0.0017**	
			ΔE			
0 days	0 months	53.7 ± 4.0^{bcB}	49.7 ± 2.1^{cB}	63.6 ± 3.3^{aB}	61.0 ± 5.4^{abB}	**0.0078**
	6 months	64.9 ± 0.2^{bA}	65.2 ± 0.3^{bA}	63.6 ± 0.1^{cB}	67.2 ± 0.1^{aAB}	**0.0001**
	12 months	66.4 ± 0.0^{cA}	66.2 ± 0.2^{dA}	71.1 ± 0.5^{aA}	68.1 ± 0.2^{bA}	**0.0001**
	P-Value	**0.0010**	**0.0001**	**0.0049**	**0.0616**	
30 days	0 months	66.8 ± 0.2^{cB}	73.0 ± 0.8^{a}	73.5 ± 0.7^{aA}	69.3 ± 1.9^{bB}	**0.0002**
	6 months	63.4 ± 0.2^{C}	67.2 ± 0.4^{aC}	67.3 ± 0.3^{aC}	64.3 ± 0.1^{cC}	**0.0001**
	12 months	67.4 ± 1.8d^{A}	74.4 ± 0.4^{bA}	70.7 ± 0.3^{cB}	81.0 ± 0.1^{aA}	**0.0001**
	P-Value	**0.0066**	**0.0001**	**0.0001**	**0.0001**	
45 days	0 months	69.4 ± 0.6^{bB}	74.8 ± 2.3^{aB}	71.7 ± 1.0^{bB}	70.9 ± 2.1^{bA}	**0.0224**
	6 months	65.3 ± 0.3^{dC}	71.8 ± 0.1^{aB}	70.4 ± 0.1^{bB}	66.1 ± 0.3^{cB}	**0.0001**
	12 months	75.9 ± 0.5^{bA}	79.2 ± 2.4^{aA}	73.1 ± 0.5^{cA}	71.0 ± 0.5^{cA}	**0.0003**
	P-Value	**0.0001**	**0.0083**	**0.0067**	**0.0047**	

^{abc} Means values in the same column not sharing a superscript are significantly different.

^{ABC} Means values in the same row not sharing a superscript are significantly different.

NS: not significant.

* Significant at p<0.05.

N= 3 replicates for each treatments.

Conclusion

Medium doses of γ-irradiation could be an effect alternative technology in post-harvest pest control because of its ability to kill insects and microorganisms of plant foods [13, 16, 17]. The Syrian Kaissy cv olive oil (SKOO) physical properties including refractive index, viscosity and color parameters appear to be influence by γ-irradiation treatment (0, 1, 2 and 3 kGy), storage time of olive fruits (0, 30 and 45days) and storage time of olive oils (0, 6 and 12 months). Further investigations on the effect of irradiation and storage time on physical properties of olive oil using higher doses and other storage conditions should be carried out.

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Author Declaration

The author reports no conflicts of interest. The author alone is responsible for the content and writing of the manuscript.

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