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Comparative Studies on Some Physicochemical Properties of Oil Extracted from Gamma Irradiated Sesame (*Sesamum indicum* L.) Seeds

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Abstract

The present study has been conducted to evaluate the characterization of the oil extracted from local cultivated sesame seeds that produced under Syrian conditions, and to explore the effect of gamma irradiation (3, 6 and 9 kGy) and storage period (6 and 12 months) on some quality characteristics of sesame seed oil. The physico-chemical properties of oil extracted from non-irradiated samples of sesame seeds were: acid value (AV) (2.79 mg KOH g^{-1} oil), peroxide value (PV) (1.69 meq O_2 kg^{-1} oil), Thiobarbituric acid (TBA) (0.022 mg MDA kg^{-1} oil), iodine value (IV) (98.36 g I_2 100 g^{-1}oil), saponification value (SV) (186.27 mg KOH g^{-1} oil), refractive index (RI) (1.471) and color values (L* = 90.14, a* = 50.76, b* = 30.47 and ΔE = 68.23). The results demonstrated that the AV, PV, TBA, IV, SN, RI and color values were significantly ($p<0.05$) altered upon irradiation and storage. Gamma irradiation and storage time increased AV, PV, TBA, IV, SN, and RI. However, all tested markers of oil that extracted from irradiated and un-irradiated seeds field within the limited value recommended by Codex Alimentarius Commission.

Keywords

Chemical properties, Gamma irradiation, Oil color, Sesame oil, Storage period

Introduction

A source of excellent vegetable oil, sesame (*Sesamum indicum* L.) has one of the highest oil contents (35-63%) among oil crops [1]. The presence of some natural antioxidants such as sesamum, sesamin, sesamolin, and sesamol in the sesame oil (SO) makes them one of the most stable vegetable oils in the world [2]. The oil of the sesame seed is very resistant to rancidity especially after hydrogenation due to the presence of natural antioxidants [3]. Recently, health beneficial functions of SO or phyto-chemicals found in SO have been reported such as changing blood lipid profiles [4].

Ionizing radiations is a modern and widely used method for food preservation. Gamma irradiation has been implicated in eliminating micro organisms in oil-rich and starch rich foods [5-9]. The ionizing radiation has the ability to start a high number of chemical changes in gas, liquid and solid phase of food. With the exposure in irradiation initially ionization of water takes place followed by the production of free radicals and peroxides [10-14]. However, a study of the relationship between radiation absorbed doses and possible changes in the composition of food stuffs must be carried out in order to comprehensively assess the acceptability of irradiated processed foods [15-17]. Any process prior to oil extraction is a key step for commercial SO production, as the color, composition and quality of SO depend upon the conditions of the process [18].

Sesame seed oil is an important vegetable oil for consumers and food industry in Syria and other region countries owing to its high nutrient content, pleasant flavor, palatability, cooking results, and industrial properties. However, up to now, no information is available about the characterization of sesame seed oil and no researches have been reported on the sesame seeds and on properties of oil extracted from sesame seed produced and marketed in Syrian. As gamma irradiation is investigated to affect the microbiological, physico-chemical, sensory characteristics and nutritive quality of several foods; this prompts the need to evaluate the effect of such treatment on the quality characteristics of SO. Therefore, the current objective was to evaluate the quality properties of oil extracted from sesame seeds produced under Syrian condition, and to study the influence of medium doses of gamma irradiation (3, 6 and 9 kGy) that recommended for arresting microorganism'scontamination on the quality properties of SO.

Materials and Methods

Treatments and analysis performed

Sesame seeds of cultivated produced in Syrian were purchased from local supermarkets and special shops in Damascus, Syria, and weighed as in the sampling plan and transferred into polyethylene pouches for irradiation. Each pouch of sesame seeds (250 g) was considered as a replicate. Then sesame seeds exposed to gamma radiation at doses of 3, 6 and 9 kGy in a ^{60}CO package irradiator. The samples were irradiated at place with a dose rate of 7.775 kGy h^{-1}, at room temperature and atmospheric pressure [10]. The irradiated and control samples of seeds were stored for 12 months at room temperature 18-25 °C under relative humidity (RH) of 50-70%. The oils from control and irradiated sesame seeds after grinding were extracted by the manual Soxhlet apparatus (Scientific Apparatus Manufacturing Company, Glas-Col Combo Mantle, USA) for 16 h, using distilled AR (analytical grade) n-hexane as the solvent [19]. Physical and chemical properties of oils extracted from irradiated and non-irradiated sesame seeds samples were performed immediately after irradiation, and after 6 and 12 months of storage.

Chemical analysis

Determination for acid value (AV) (Oleic acid %) in term of mg KOH g^{-1} oil, peroxide value (PV) in term of meq O_2 kg^{-1} oil, iodine value (IV) in g I_2 100 g^{-1} and saponification (specification) value (SV) in term of mg KOH g^{-1} oil sample, and the refractive index (RI) at 25 °C were determined according to standard methods [19]. TBA number (Thiobarbituric acid) in mg MDA kg^{-1} sample was measured according to IUPAC direct method [20].

Color measurement

The color of sesame oil was measured using AvaSpec Spectrometer Version 1, 2 June 2003 (Avantes, Holland) and expressed as colour L* (lightness), a* (redness), and b* (yellowness) values. Reflectance values were obtained at wavelength of 568 nm by exposing the samples to the illuminant [7]. The reference for calculating the delta E value was using by setting the enter page background of the yellow color parameters (L = 100, a = 25 b = 100), and these values were used during the experimental periods. The reported results (L*, a*, b*) are the mean of 9 determinations

Statistical analysis

Values represented are the means and standard deviations (mean ± SD) for 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: $p<0.05^*$, $p<0.001^{**}$ [21].

Results and Discussion

Effect of gamma irradiation and storage period on acid value of sesame oil

The results in table 1, show the effect of different doses of gamma irradiation and different storage periods on the acid value (AV) of sesame seeds oil. The results indicate that the AV in the oil extracted from non-irradiated control sesame seed samples found to be (2.7 mg KOH g^{-1} oil,). The AV was higher than that reported for Brazzaville-Congo sesame oil (1.8%) [22] and below the minimum acceptable value of (4.0 mg KOH g^{-1} oil) for sesame recommended by the Codex Alimentarius Commission for oil seeds [1]. Indeed, free fatty acids (FFA) were partly formed by hydrolysis of triglycerols, which was promoted by the presence of food moisture [23]. Regarding the effects of gamma radiation on the AV, a small, but statistically significant ($p<0.05$) changes in AV as a result of irradiation of sesame seeds at doses of 3 and 9 kGy. The decrease ($p<0.05$) in AV was observed in oil extracted from sesame seed exposed to doses of 3 kGy (2.59%) and an increase ($p<0.05$) in AV was observed in oil extracted from sesame seed exposed to doses of 9 kGy (2.96%). While those treated at 6 kGy were similar to control. Total acidity values of irradiated and non-irradiated sesame seed oil samples are very small between 2.59 and 2.96% and lies within desirable limits 0.0–4.0 mg KOH g^{-1} oil [1, 24]. During storage, the AV of SO increased ($p<0.05$) in all samples regardless of the irradiation dose. After 12 months of storage, the AV of oil extracted from samples irradiated with 6 kGy (3.25%) and 9 kGy (3.23%) were significantly ($p<0.05$) lower than that of non-irradiated control samples (3.43%). While, the AV of oil extracted from samples irradiated with 3 kGy (3.62%) was significantly ($p<0.05$) higher than that of non-irradiated control samples (3.43%). The lower AV in oil extracted from samples treated with higher doses (6 and 9 kGy) and higher AV in oil extracted from samples treated with lower dose (3 kGy) might be attribute to the effect of higher doses on reduce and lower dose on stimulate the enzyme activity. AV represents free fatty acid content due to enzymatic activity and is usually indicative of spoilage [12]. The results of the present study are in agreement with that of Bhatti et al. [6] who reported an increase in free fatty acids for oil extracted from gamma irradiated almond seeds, might be due to slight random hydrolysis of triglycerol molecules to free fatty acids and diacylglycerols [10].

Effect of gamma irradiation and storage period on peroxide value of sesame oil

The changes of the peroxide value (PV) during gamma radiation processing and storage time are shown in table 1. The low PV recorded for oil extracted from non-irradiated control samples of sesame seeds (1.69 meq O_2 kg^{-1} oil) is an indication of its relative stability to oxidative rancidity. The PV is measure of the content of hydroperoxides, which are primary oxidation products. As oxidation takes place the double bonds in the unsaturated fatty acids are attacked forming peroxides. Fresh oils have been shown to have PVs lower than 10 mg g^{-1} oil and oil become rancid when the PV ranges from 20.0 to 40.0 meq O_2 kg^{-1} oil [25].

Immediately after irradiation, there was a significant increase (p<0.05) in the PV of oil from sesame seed samples irradiated with 3, 6 and 9 kGy. While after 6 and 12 months of storage, there was no significant differences (p<0.05) in the PV of oil from irradiated or un-irradiated sesame seed samples. PVs of SOs extracted from irradiated and non-irradiated samples increased with increased storage time and the increase was greater in oil extracted from non-irradiated samples than that of irradiated ones (Table 1). Given the low moisture content of sesame seeds (3.70%) [8]. It is most probable that free fatty acids were produced in small amount in irradiated seeds through triglycerides hydrolyses. According to the literature, irradiation of high moisture content foods results in high hydroxyl radical concentrations which triggers fat oxidation, leading to changes in fatty acid composition of fatty foodstuffs [26]. Aric et al. [5] have reported that the peroxide, which is formed after irradiation exposure, breaks the dual links of oxygen, hydroperoxide and hydroxide free radicals and removes the dual link feature. Irradiation results in the formation of free radicals, such as lipid radicals, super oxide radicals and H_2O_2, an catalyzes another oxidation process [27]. The oxidation of oils and fats is one of the main causes of the deterioration of organoleptic and nutritional characteristics of food stuff [28].

Effect of gamma irradiation and storage period on TBA value of sesame oil

Lipid oxidation in sesame oil was measured in terms of thiobarbituric acid (TBA) values expressed as mg malonaldehyde (MDA) kg^{-1} oil. Data for oil extracted from irradiated and non-irradiated sesame seeds are shown in table 1. As shown in table a small, but statistically significant changes in TBA value as a result of irradiation of sesame seeds at doses up to 9 kGy. Oil extracted from non-irradiated control samples had significantly lower (p<0.01) initial (day 0) TBA values (0.22 mg MDA kg^{-1} oil) than those extracted from samples irradiated with 6 kGy (0.25 mg MDA kg^{-1} oil). While, oil extracted from non-irradiated control samples had significantly higher (p<0.01) initial (day 0) TBA values (0.22 mg MDA kg^{-1} oil) than those extracted from samples irradiated with 3 kGy (0.19 mg MDA kg^{-1} oil). Present oxidation results of sesame oil are in general agreement with those reported in previous studies which found significant changes in the TBA counts of fermented sausage [29] after irradiation. On other hand, this findingis directly contradictory to those reported in previous studies which found that PV at low irradiation dose (up to 5 kGy) there was no significant change in TBA in chicken meat [30]. Since there are some differences in experimental design among the previous studies, such as the source of irradiation, the properties of the raw materials, and the preparation methods of end products, etc. It is not easy to compare the results of all previous studies with those of this study. However, these contradictory findings may reveal the complexity in understanding of chemical characteristics of irradiated food [31]. Oil quality is affected by several factors, such as agronomic techniques, sensorial conditions, sanitary state of drupes, ripening stage, harvesting and carriage systems, methods and duration of storage, processing technology, cultivar and growing medium [32]. TBA values of both, oil extracted from non-irradiated control sample of sesame seeds, and oil extracted from sesame seeds irradiated with 3 and 9 kGy increased significantly (p<0.05) as the storage time increased. Ahn and Nam [33] pointed out that as the storage time increased, overall lipid oxidation of irradiated beef increased. TBA values of oil extracted from irradiated and non-irradiated sesame seed samples during the storage periods are very small, between 0.21 and 0.26 mg MDA kg^{-1} oil, and lie within desirable limits 0.0-3.0 mg MDA kg^{-1} oil is supposed to be less than 5 mg MDA kg^{-1} oil for good quality products and the maximum edible limit is about 7-8 mg MDA kg^{-1} oil [34]. Therefore, all samples of the sesame oil in the present study can be considered as good quality products in terms of TBA value.

Effect of gamma irradiation and storage period on iodine value of sesame oil

Table 1 present the results of iodine values (IV) of oil extracted from irradiated and non-irradiated SO. The IV of oil extracted from non-irradiated control sample of sesame seed (98.36 g iodine 100 g^{-1} oil) was lower than that reported for other varieties of sesame (103 to 117 g iodine 100 g^{-1} oil) [22, 35].

The IV is a measure of the degree of the un-saturation in oil; it gives valuable information about the drying properties of the oil as well as the extent of adulteration of the oil [36]. Oils are classified into drying, semi drying and non-drying according to their IVs. Drying oils have IV above 100 [37]. Science the IV of SO was little lower than 100 it could be classified as non- drying oil, highly unsaturated and suggests that they contain high levels of oleic and linoleic acids [38].

The effect of various levels of gamma irradiation on IV is shown in table 1. While the lowest values were acquired from the oil of the sample which is not exposed to irradiation; and relating to the irradiation dosages these values increased (p>0.05), and finally the highest values recorded in the sample was treated with 3 kGy irradiation (Table 1). These findings are directly contradictory to those reported in previous studies which found a gradual decrease in IVs was noticed in irradiated SOs (from 1 kGy to 7.5 kGy) and reached its maximum decrease at highest dose of 7.5 kGy as compared with the control [35].

Table 1: Effect of gamma irradiation and storage period on acid value, peroxide value, TBA value, iodine number, Saponification value and refractive index of sesame oil.

Treatment		Control	3 KGY	6 KGY	9 KGY	P level
						Storage period (Months) **Acid value (mg KOH g^{-1} oil)**
0		2.79 ± 0.02^{bC}	2.59 ± 0.01^{cC}	2.83 ± 0.06^{bB}	2.96 ± 0.03^{aB}	**
6		3.06 ± 0.01^{aB}	3.03 ± 0.01^{aB}	2.86 ± 0.00^{bB}	2.78 ± 0.05^{cC}	**
12		3.43 ± 0.08^{bA}	3.62 ± 0.00^{aA}	3.25 ± 0.06^{cA}	3.23 ± 0.02^{cA}	**
P-level		**	**	**	**	
						Peroxide Value (m Eq O_2 kg^{-1} oil)
0		1.69 ± 0.02^{bC}	1.86 ± 0.03^{aB}	1.87 ± 0.03^{aB}	1.82 ± 0.01^{aB}	**
6		1.86 ± 0.06^{aB}	1.88 ± 0.05^{aB}	1.88 ± 0.03^{aB}	1.85 ± 0.02^{aB}	NS
12		3.60 ± 0.03^{aA}	3.41 ± 0.19^{aA}	3.56 ± 0.10^{aA}	3.39 ± 0.04^{aA}	NS
P-level		**	**	**	**	
						TBA value (mg MDA kg^{-1} oil)
0		0.022 ± 0.001^{bB}	0.019 ± 0.001^{cC}	0.025 ± 0.001^{aA}	0.022 ± 0.000^{bB}	**
6		0.021 ± 0.001^{aC}	0.020 ± 0.001^{bB}	0.020 ± 0.001^{bB}	0.020 ± 0.001^{bC}	**
12		0.025 ± 0.001^{bA}	0.025 ± 0.001^{bA}	0.024 ± 0.001^{cA}	0.026 ± 0.001^{aA}	**
P-level		**	**	**	**	
						Iodine value (g I_2 100 g^{-1} oil)
0	98.36 ± 2.13^{bC}		101.32 ± 1.14^{aB}	99.87 ± 0.67^{abC}	100.29 ± 0.52^{abC}	NS
6	107.78 ± 0.89^{aA}		107.82 ± 0.86^{aA}	105.35 ± 0.27^{bA}	105.91 ± 0.27^{bA}	**
12	102.25 ± 0.22^{aB}		103.22 ± 0.91^{aB}	102.58 ± 0.14^{aB}	102.96 ± 2.00^{aB}	NS
P-level	**		**	**	**	
						Saponification value (mg KOH g^{-1} oil)
0	186.27 ± 0.80^{bA}		185.64 ± 0.04^{bA}	190.79 ± 0.10^{aA}	190.61 ± 0.61^{aA}	**
6	183.56 ± 1.29^{aB}		182.52 ± 0.59^{aB}	183.15 ± 1.11^{aC}	182.40 ± 2.31^{aC}	NS
12	185.79 ± 0.80^{aA}		184.94 ± 0.18^{bA}	185.26 ± 0.15^{abB}	185.57 ± 0.13^{abB}	NS
P-level	*		**	**	**	
						Refractive Index (nD 25 ^{0}C)
0	1.471 ± 0.0001^{aB}		1.471 ± 0.0001^{aB}	1.471 ± 0.0001^{aA}	1.471 ± 0.0001^{aA}	**
6	1.471 ± 0.0000^{aB}		1.471 ± 0.0000^{aB}	1.470 ± 0.0000^{aB}	1.470 ± 0.0000^{aB}	**
12	1.472 ± 0.0001^{aA}		1.472 ± 0.0001^{aA}	1.471 ± 0.0000^{aA}	1.471 ± 0.0000^{aA}	**
P-level	**		**	**	**	

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

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

NS: not significant.

* Significant at p<0.05.

** Significant at p<0.01.

IVs of oil extracted from irradiated (3, 6 and 9 kGy) and non-irradiated control sample of sesame seeds increased significantly ($p<0.05$) as the storage time increased. Which may be explained by a dose dependent effect of irradiation on the fatty acid profile [39]. This author observed a trend toward an increase in the amount of saturated fatty acids (SFAs) and a decrease in the amount of unsaturated fatty acids (USFAs) in the triacylglycerol composition of irradiated sesame, peanut and sunflower seeds.

Effect of gamma irradiation and storage period on saponification value of sesame oil

The results of saponification value (SV) of sesame oil extracted from irradiated and non-irradiated seeds are as shown in table 1, as a function of storage time. The SV of oil extracted from non-irradiated control samples of sesame seeds is 186.27 mg KOH g^{-1} oil, which was lower than 196.00 mg KOH g^{-1} oil that reported by Biswas et al. [40] for sesame oil, and falls within the recommended codex Alimentarius for edible sesame oil (186-195 mg KOH g^{-1} oil) [41]. Also, SV of sesame oil presented in this study was lower than those range reported for varieties of melon oil (225 mg KOH g^{-1}), coconut oil (200-250 mg KOH g^{-1}), butter fat (220-241 mg KOH g^{-1}), cotton seed oil (190-200 mg KOH g^{-1}) and soybean oil (190-194 mg KOH g^{-1}) [37]. This shows that the oil does not have potential for use in soap making industry and for thermal stabilization of poly vinyl chloride (PVC) [1]. SV is an indicator of the average molecular weight and hence, chain length. It is inversely proportion to the molecular weight of the lipid [42].

It is seen in table 1, that SVs increased (p<0.05) at doses of 6 and 9 kGy, and decreased (p<0.05) with storage time, which indicated that large original molecules of oils containing long-chain fatty acids degraded to smaller molecules as a results of oxidation and cleavage of bonds [39]. Present SV results of sesame oil are in general agreement with those reported by our group on this parameter in oil extracted from pistachio also showed that gamma irradiation and storage period effected SV of pistachio oil significantly (p<0.05). The SV of the oil extracted from non-irradiated samples was lower than those extracted from irradiated samples. During storage, the SV of the oil extracted from both irradiated and non-irradiated samples decreased (p<0.05) [13]. The oils SVs decreased upon storage, which indicated that large original molecules of oils containing long-chain fatty acids degraded to smaller molecules as a result of oxidation and cleavage of bonds [34].

Effect of gamma irradiation and storage period on refractive index of sesame oil

The refractive index (RI) of sesame oils extracted from non-irradiated control samples of seed at 25 °C was 1.471 (Table 1), showed that it is not as thick as most drying oil whose refractive index fell between 1.475 and 1.485 [37]. These resultsaresimilar to that reported for Bangladesh sesame (1.475%) [40] and falls within the recommended codex of 1.465 and 1.469 for sesame oil [41]. The refractive value of sesame oil, present in this study, is very similar to those reported for olive oil (1.465 – 1.466), sunflower oil (1.465 – 1.472), cottonseed oil (1.474), soybean oil (1.472), brassica oil (1.470) and linseed oil (1.478) [40].

Refractive index is used by most processors to measure the change in un-saturation as the fat or oil is hydrogenated. The refractive index of oils depends on their molecular weight, fatty acid chain length, degree of conjugation [42].

The effect of irradiation exposure on the refractive index of SO was found insignificant (Table 1), which is similar to that reported for black cumin oils [5].

Effect of gamma irradiation and storage period on color of sesame oil

The effects of gamma irradiation and storage time on color of SO are shown in table 2. In the present study significant (p<0.05) change in color parameters (L*-value, a*-value, b*-value and ΔE) due to irradiation was found in SO samples at time zero and after 12 months of storage. Immediately after irradiation, the L*-value of oil extracted from seed irradiated with 3 kGy (91.75) was significantly (p<0.05) higher, while the L*-value of oil extracted from seed irradiated with 9 kGy (89.29) was significantly (p<0.05) lower than that of non-irradiated control samples (90.14). The a*-value of oil extracted from seed irradiated with 3 kGy (51.56) was significantly (p<0.05) higher, while the a*-value of oil extracted from seed irradiated with 6 kGy (49.29) was significantly (p<0.05) lower than that of non-irradiated control samples (50.52). Finally, the b*-value and ΔE of oil extracted from seed irradiated with 6 kGy (32.11 and 66.29) and 9 kGy (31.04 and 67.82) were significantly (p<0.05) lower than that of non-irradiated control samples (30.47 and 68.23) respectively. During storage, the color parameters (L*-value, a*-value and b*-value) of SO decreased regardless of irradiation dose. After 12 months of storage, the L*-value, a*-value, b*-value and ΔE of oil extracted from seed irradiated with highest dose (9 kGy) (84.58, 49.15, 29.41 and 71.84) were significantly (p<0.05) higher than that of non-irradiated control samples (83.42, 47.53, 26.67 and 67.97) respectively. Previous work by other groups on these color parameters in other vegetable oils also showed an effect of irradiation treatment and storage period [43]. The effect of irradiation dose up to 7 kGy was in-statistically (p> 0.05) for parameters L* and a*, while parameter b* increased (p<0.05) at dose of 7 kGy[44]. Gogle and Ova [45] reported statistically

Table 2: Effect of gamma irradiation and storage period on color change of Sesame oil.

Treatment	Control	3 KGY	6 KGY	9 KGY	P-level
		Storage period/(Months)			L
0	90.14 ± 0.02^{bA}	91.75 ± 0.30^{aA}	90.10 ± 0.12^{bA}	89.29 ± 0.04^{cB}	**
6	82.17 ± 0.04^{aC}	88.70 ± 0.03^{bB}	86.72 ± 1.17^{cB}	92.40 ± 0.02^{aA}	**
12	83.42 ± 0.19^{bB}	84.19 ± 0.13^{aC}	82.26 ± 0.39^{cC}	84.58 ± 0.15^{aC}	**
P-level	**	**	**	**	
			a		
0	50.76 ± 0.07^{bB}	51.62 ± 0.39^{aB}	49.56 ± 0.64^{cB}	50.52 ± 0.08^{bB}	0.71**
6	53.58 ± 0.09^{dA}	56.97 ± 0.12^{aA}	54.18 ± 0.09^{cA}	56.60 ± 0.07^{bA}	0.18**
12	47.53 ± 0.31^{cC}	48.64 ± 0.13^{bC}	49.00 ± 0.27^{abB}	49.15 ± 0.17^{aC}	0.43**
P-level	**	**	**	**	
			b		
0	30.47 ± 0.44^{dA}	30.88 ± 0.17^{cA}	32.11 ± 0.55^{aA}	31.04 ± 0.17^{bA}	**
6	26.37 ± 0.36^{aB}	23.55 ± 0.14^{cB}	25.13 ± 0.13^{bC}	25.35 ± 0.07^{bC}	**
12	26.67 ± 0.97^{bB}	22.45 ± 0.96^{cB}	29.05 ± 0.50^{aB}	29.41 ± 0.11^{aB}	**
P-level	**	**	**	**	
			ΔE		
0	68.23 ± 0.35^{aB}	68.40 ± 0.36^{aC}	66.29 ± 0.84^{bC}	67.82 ± 0.07^{aC}	**
6	68.88 ± 0.31^{dA}	72.08 ± 0.16^{aA}	69.51 ± 0.15^{cA}	70.07 ± 0.04^{bB}	**
12	67.97 ± 0.29^{cB}	70.11 ± 0.43^{bB}	68.00 ± 0.34^{cB}	71.84 ± 0.13^{aA}	**
P-level	*	**	**	**	

^{abc} Means values in the same row not sharing a superscript are significantly different.
^{ABC} Means values in the same column not sharing a superscript are significantly different.
NS: not significant.
*Significant at p<0.05.
**Significant at p<0.01.

significant changes in parameter L* and b* values for pine nuts after irradiation at different doses. On other hand, the color of the samples of almonds treated with 0, 3, 7 and 10 kGy showed a gradual darkening during storage, irrespective of the treatment which they received [46].

The color of fat and oil is considerable practical importance and figures prominently in the trading rules for these materials. Pure fat, fatty acids, esters and the other usual lipid derives are color less and essentially transparent to visible light (400-700 mμ) [47]. The color formation in sesame oil during processes could be attributed to both non-enzymatic browning and phospholipids degradation during heating storage or irradiation [38]. The non-enzymatic browning is favored by heat and irradiation treatment and includes a wide number of reactions such as Millard reaction, caramelization and chemical oxidation of phenols [48]. For instance, in the case of Millard reaction, the sesame seed contains the required reaction, sugars and amine groups as found in protein molecules, to give the Millard reaction products [49].

Conclusion

The results of this study demonstrate that, the sesame oil extracted from irradiated and non-irradiated seeds, immediately after irradiation and after 12 months of storage had an acceptable initial quality. The Codex Alimentarius Commission expressed the permitted maximum and minimum of those quality remarkets for SO to be (maximum AV of 10.0 mg KOH g^{-1}, and PV of 10 mequiv.g O_2 kg^{-1} of oil), IV (104 to 120 g iodine 100 g^{-1} oil), specification value (186 to 195 g KOH g^{-1} oil), and Refractive index (1.465 to 1.469).

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Conflict of Interest

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

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