JAP&T
TPA-Timişoara

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Journal of Agroalimentary Processes and Technologies 2020, *26* (4), 441-448

Journal of Agroalimentary Processes and Technologies

Comparison between the physicochemical quality of oil obtained from irradiated and non-irradiated peanut (*Arachis hypogaea* L.) seeds

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Abstract

The purpose of this study was to evaluate the occurrence of lipid oxidation in oil extracted from peanut seeds which were treated with 3, 6 and 9 kGy of gamma irradiation and stored for 12 months. Physicochemical properties of the peanut oil were determined. The analyses were focused in the main chemical and physical constants of oil: acid value (AV), peroxide value (PV), iodine value (IV), Saponification value (SV), Thiobarbituric value (TBA), Refractive index (RI), and color values (L*, a*, b* and ΔE- values). The results indicated that the chemical properties such as IV, SV, TBA and RI of the oils extracted from gamma irradiated peanut were almost unaffected; the AV and PV increased. Color parameters L* and b* decreased ($p<0.05$) after irradiation, while color parameters a* and ΔE increased ($p<0.05$). The overall physicochemical properties values of oil extracted from peanut seed treated with 0, 3, 6 and 9 kGy and stored for 0, 6 and12 months were falls within the recommended codex for edible peanut oils.

Keywords: Chemical properties, Gamma irradiation, oil color, peanut oil, Storage period

1. Introduction

The majority of the edible oils and fats produced worldwide annually are derived from plant sources and is referred as vegetable oils that are an important group of agricultural commodity, in terms of value in the world trade [1]. Peanut oil is one of the major oils in the human diet, which generally contains 55-65% monounsaturated fatty acids, 26-28% polyunsaturated fatty acids, and 17-18% saturated fatty acids, and minor components including phospholipids, sterols, tocols, fat soluble vitamins, or color pigments [2,3].

The major fatty acids identified in peanut oil were 50.36% oleic acid (C18:1), 36.40% linoleic acid (18:2), 11.10% palmitic acid (C16:0) and 2.14% stearic acid (C18:0). The presence of high amount of the essential linoleic acid suggests that the peanuts oil is highly nutrient [3,4].

As other oil seeds, peanut seeds are susceptible to infestation by molds, insects and fungi [5]. Various post-harvest procedures have been applied for control of insects and mites in stored products such as chemical, biological and physical control or combination of these techniques, but none of these methods offers a complete control of toxigenic moulds [6].

Gamma rays belong to ionizing radiation and are the most energetic form of such electromagnetic radiation, having the high energy level. Therefore, they are more penetrating than other types of radiation such as alpha and beta rays [7]. Gamma irradiation processing is mainly employed to extend the shelf-life and secure the quality of foods by decreasing the microbial appropriate approach for the disinfection and decontamination of cereals, spices, dried fruits and nuts [6,8,9,10,11,12]. Irradiation of high lipid-containing materials could lead to lipid peroxidation and consequently to development of off-flavour and off-odour [4,13,14,15]. Hence, high dose irradiation is generally not carried out with lipid rich materials. In

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the present study, it is intended to evaluate if the application of medium irradiation doses (3, 6 and 9 kGy) still maintain peanut oil chemical and physical profiles unaffected. The analyses were focused on the main chemical and physical constants of oil: acidity, peroxide, iodine, saponification, thiobarbituric, refractive index, and color values. Furthermore, the effects of gamma irradiation on physio-chemical properties of oil extracted from peanut seed stored at room temperature for different periods were evaluated, in order to understand the possible interactions among these two main factors (irradiation and storage time).

2. Materials and methods

2.1. Treatments and analysis performed

Peanut seed of local cultivar were purchased from local supermarkets and special shops in Damascus, Syria, and 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 [8]. The oils from control and irradiated peanut 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 [16]. Physical and chemical properties of oils extracted from irradiated and non-irradiated peanut seeds samples were performed immediately after irradiation, and after 6 and 12 months of storage.

2.2. Chemical analysis of oils

Determination of acidity value (AV) (Oleic acid %) in terms of mg KOH g^{-1} oil, peroxide value (PV) in terms of meq O_2 kg^{-1} oil, iodine value (IV) in g I_2 100 g^{-1}, specification (saponification) value (SV) in terms of mg KOH g^{-1} oil sample and the refractive index (RI) at 25 ^oC were determined according to standard methods [16]. TBA number (Thiobarbituric acid) in mg MDA kg^{-1} sample was measured according to IUPAC direct method [17].

2.3. Color measurement

The color of peanut oil was measured using AvaSpec Spectrometer Version 1, 2 June 2003 (Avantes, Holland) and expressed as color L* (lightness), a* (redness), and b* (yellowness) values. Reflectance values were obtained at wave length of 568 nm by exposing the samples to the illuminant [11]. The reported results (L*, a*, b*) are the mean of 9 determination.

2.4. 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 statistically considered. The degree of significance was denoted as: $p<0.05$*, $p<0.01$** [18].

3. Results and discussion

3.1. Physicochemical properties of peanut seeds oil

The overall physicochemical properties of the oil extracted from non-irradiated control samples of peanut seed were; acid value (1.44 mg KOH g^{-1} oil), peroxide value (2.82 meq g O_2 kg^{-1} oil), TBA value (0,021 mg MDA kg^{-1} oil), iodine value (95.24 g iodine 100 g^{-1} oil), saponification value (192.60 g KOH g^{-1} oil), and refractive index (1.469). These values fall within the recommended codex for edible peanut oils [19]. Physical properties of lipids derived directly from their chemical structures and functional groups and greatly influenced the functions of lipids in foods and the method required for their manipulation and processing [20]. They can also be used to assess the purity of quality of lipid material in reference to known standards of preferred characteristics [15,21,22]. It has been shown that oil becomes rancid when the peroxide value ranges from 20.0 to 40 meq O_2 kg^{-1} oil [23]. On the other hand, according to the Codex Alimentarius Commission, the acid and peroxide values for the virgin vegetable oils may be maximum 10 mg KOH g^{-1} and 20 meq O_2 kg^{-1} oil, respectively [22]. Therefore, the peanut seed oil studied can be regarded as an edible oil with good quality.

3.2. Effect of gamma irradiation and storage period on acidity value of peanut oil

The acidity level of peanut seed oil was 1.44 mg KOH g^{-1} oil before irradiation and increased ($p<0.05$) to 1.56 mg KOH g^{-1} oil after the 9 kGy irradiation. It was found that the effect of irradiation exposure on acidity value of peanut oil samples was statistically important ($p<0.05$). According to the research results, if the dose level of irradiation increases, acidity value increases proportionally.

Table 1. Effect of gamma irradiation and storage period on biochemical properties of Peanut oil

Storage period/ (Months)	0	6	12	P-level
Treatments		**Acid value (mg KOH g^{-1} oil)**		
Control	1.44 ± 0.01^{bB}	1.50 ± 0.02^{cB}	2.28 ± 0.06^{bA}	**
3 kGy	1.47 ± 0.02^{bB}	1.49 ± 0.03^{cB}	2.29 ± 0.05^{abA}	**
6 kGy	1.47 ± 0.02^{bC}	1.65 ± 0.02^{bB}	2.28 ± 0.05^{bA}	**
9 kGy	1.56 ± 0.06^{aC}	$1.73\pm0.03a^{B}$	2.36 ± 0.01^{aA}	**
P-level	*	**	NS	
		Peroxide Value (meqO_2 kg^{-1} oil)		
Control	2.82 ± 0.13^{cC}	5.47 ± 0.12^{bB}	6.98 ± 0.09^{cA}	**
3 kGy	3.65 ± 0.04^{bC}	5.22 ± 0.06^{cB}	7.00 ± 0.31^{aA}	**
6 kGy	4.64 ± 0.17^{aC}	5.76 ± 0.10^{aB}	7.66 ± 0.06^{bA}	**
9 kGy	4.38 ± 0.24^{aC}	5.74 ± 0.17^{aB}	9.50 ± 0.11^{bA}	**
P-level	**	**	**	
		TBA value (mg MDA kg^{-1} oil)		
Control	0.021 ± 0.001^{aA}	0.022 ± 0.001^{aA}	0.021 ± 0.002^{aA}	NS
3 kGy	0.021 ± 0.001^{aA}	0.022 ± 0.001^{aA}	0.022 ± 0.001^{aA}	NS
6 kGy	0.020 ± 0.001^{bA}	0.021 ± 0.002^{aAB}	0.022 ± 0.002^{aA}	NS
9 kGy	0.020 ± 0.001^{bC}	0.021 ± 0.001^{aB}	0.022 ± 0.002^{bA}	**
P-level	**	NS	NS	

^{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 $p<0.01$.

Our results are in agreement with the previously reported findings of Al-Bachir and Koudsi [24] who also observed that the free fatty acid of black cumin increased with increasing the doses of irradiation treatment (up to 10 kGy). Wen et al. [25] found no significant change in acidity following 4, 8 and 14 kGy gamma irradiation in lyceum fruit. Jittrepotch et al. [26] reported that the free fatty acids of peanut seed oil were significantly increased ($p<0.05$) when these were treated by microwave irradiation. The acid value of the oil extracted from irradiated and non-irradiated peanut seed samples increased ($p<0.05$) during the storage period (Table 1). However, hydrolysis of glycerides to yield fatty acid occurs during storage [27].

3.3. Effect of gamma irradiation and storage period on peroxide value of peanut oil

Peroxide value is an index of rancidity. The high peroxide value of oil indicates a poor resistance of the oil peroxidation during storage [28] and it serves as an indicator of the oil to resist lypolytic hydrolysis and oxidative deterioration [15].

The results in Table 1 indicate that immediately after irradiation and after 12 months of storage, all used doses (3, 6 and 9 kGy) of gamma irradiation significantly ($p<0.05$) increased the peroxide value of peanut oil. This is in agreement with Chiou [29] who revealed that the peroxide content of peanut oils extracted from the irradiated peanuts increased with increased irradiation dose (2.5, 5.0, 7.5 and 10 kGy). According to Bhatti et al. [30], and De Camargo et al. [2], gamma irradiation (8 -10 kGy) increased primary and secondary oxidation products of peanuts. Zeng et al. [31] reported that the peroxide value was increased significantly after pulsed electric field treatment. However, the peroxide value of peanut oil increased slightly at 10 min UV-irradiation time [32]. During storage, the peroxide value of peanut seed oil increased ($p<0.01$) in all samples regardless of the irradiation dose. Primarily, due to oxidative reaction of lipids, peanuts shelf-life as well as its sensory quality decreases with storage time [33].

3.4. Effect of gamma irradiation and storage period on TBA value of peanut oil

Lipid oxidation, expressed as malondialdehyde (MDA) content of oil extracted from control samples of peanuts (0.021 mg MDA kg-1 oil), was higher ($p<0.05$) than those of oil extracted from samples treated with 6 and 9 kGy (0.020 mg MDA kg^{-1} oil) (Table 1). Regarding the effect of storage

time on the TBA values, only the TBA value increased ($p<0.05$) in samples treated with 9 kGy. Our results, related to the TBA analyses are consistent with previous reports which also revealed no significant difference in TBA between irradiated with 3 kGy and un-irradiated almond [13], pistachio [9], and peanut [10], and sunflower [12].

3.5. Effect of gamma irradiation and storage period on iodine value of peanut oil

Iodine value is the measure of the proportion of unsaturated acids present. The principle of iodine value is due to the reactivity of double bonds with halogens. The data presented in Table 2 illustrate that the iodine value of the oil extracted from non-irradiated peanut seeds (95.24 g I_2 100 g^{-1} oil) was in good agreement with those indicated by Afify et al. [34] for Egyptian peanut seed oil (95.24 g I_2 100 g^{-1} oil). While iodine value of peanut seed oil present in this study was much higher than that reported for Nigerian variety of peanut seed oil (65.52 g I_2 100 g^{-1}) [35].

No significant ($p<0.05$) differences were found in relation to the iodine value of oil extracted from peanut seed samples treated with 0, 3, 6 or 9 kGy and stored for 0, 6 or 12 months. In contrast, previous work on this parameter on sesame [15], almond [13], pistachio [9], and walnut [8] and showed that the iodine value decreases as irradiation dose increases. Afify et al. [34] reported that the decrease in iodine values of peanut oil ranged from 95.24 to 88.44 g I_2 100 g^{-1} oil from the control to 7.5 kGy, respectively. The iodine value of the oil extracted from non-irradiated peanut seed samples increased ($p<0.05$) during the storage period from 95.24 g I_2 100 g^{-1} oil at day zero to 100.12 and 98.03 g I_2 100 g^{-1} oil after 6 and 12 months of storage respectively.

3.6. Effect of gamma irradiation and storage period on saponification value of peanut oil

The oil extracted from non-irradiated control samples of peanut seeds had high saponification values (192.24 mg KOH g^{-1} oil) implying that is the most unsaturated. Since saponification value is inversely proportional to the molecular weight of the fatty acid present in oil, it can be concluded that peanut seed oil contains glycerides with the highest molecular weights [15].

However, no significant ($p<0.05$) differences was observed in the saponification values of peanut oil extracted from peanut seed samples treated with 0, 3, 6 or 9 kGy, when the test carried out immediately after irradiation and after 6 and 12 months of storage. During storage, saponification values increased in oil extracted from both non-irradiated (control) samples and samples irradiated with 6 and 9 k Gy, which indicated that large original molecules of oils containing long-chain fatty acids degraded to smaller molecules as results of oxidation and cleavage of bonds [24].

3.7. Effect of gamma irradiation and storage period on refractive index of peanut oil

Refractive index is the measure of the thickness as well as purity or clarity of the oil. The peanut seed oil extracted from non-irradiated (control) samples showed a refractive index of 1.469, which was similar to those reported by Gohari Ardabili et al. [22] for pumpkin seed oil (1.466), and within the range reported for canola, rapeseed and corn oils [21]. The refractive index of peanut oil in the present study showed that it is not as thick as most drying oil whose refractive indices fell between 1.475 and 1.485 [36].

There was no difference ($p>0.05$) for the values of refractive between the irradiated and non irradiated samples. Our results are in accordance with the previously reported findings of Bhatti et al., [30] who also did not observe any significant change in refractive indices between the control and irradiated peanut oils.

3.8. Effect of gamma irradiation and storage period on color of peanut oil

Color values for oil extracted from non-irradiated and irradiated peanut seed are shown in Table 3. The effect of gamma irradiation doses of 3, 6 and 9 kGy was significant ($p<0.05$) for parameters L*, a*, b*, and ΔE immediately after irradiation, parameter L* decreased ($p<0.05$) at doses of 3, 6 and 9 kGy, and parameter a* decreased ($p<0.05$) at dose of 3 kGy. While, parameter b* decreased ($p<0.05$) at doses of 3, and 9 kGy, and increased ($p<0.05$) at a dose of 3 kGy. However, parameter ΔE increased ($p<0.05$) at doses of 3, and 9 kGy, and decreased ($p<0.05$) at a dose of 3 kGy. During storage, L*, a*, and ΔE values for oil extracted from non-irradiated and irradiated peanut seed decreased ($p<0.05$), while b* values increased ($p<0.05$). At the end of the storage time (after 12 months), the L* of oil extracted from peanut seeds irradiated with 6 kGy was lower ($p<0.05$), the a* value of oil extracted from peanut seeds irradiated with 6 kGy and 9 kGy

Table 2. Effect of gamma irradiation and storage period on biochemical properties of Peanut oil

Storage period/ (Months)	0	6	12	P-level
Treatments		**Iodine number (g I_2 100 g^{-1} oil)**		
Control	95.24 ± 0.18^{aC}	100.12 ± 1.14^{bB}	98.03 ± 0.38^{aB}	**
3 kGy	96.95 ± 2.32^{aB}	100.06 ± 0.36^{cB}	98.60 ± 1.02^{aAB}	NS
6 kGy	97.98 ± 1.09^{aB}	100.90 ± 1.45^{aB}	97.77 ± 1.37^{aB}	*
9 kGy	96.39 ± 2.82^{aA}	99.39 ± 0.19^{aB}	97.68 ± 1.84^{aA}	NS
P-level	NS	NS	NS	
		Saponification value (mg KOH g^{-1} oil)		
Control	192.60 ± 2.18^{aB}	192.58 ± 0.28^{aB}	195.72 ± 0.40^{aA}	*
3 kGy	193.50 ± 1.93^{aAB}	192.71 ± 0.55^{aB}	195.49 ± 0.14^{aA}	NS
6 kGy	190.54 ± 1.00^{aC}	192.51 ± 0.58^{aB}	195.36 ± 0.38^{aA}	**
9 kGy	192.23 ± 1.12^{aB}	193.16 ± 0.46^{aB}	195.57 ± 0.59^{aA}	**
P-level	NS	NS	NS	
		Refractive Index (at 25 ^{0}C)		
Control	1.469 ± 0.0001^{aB}	1.466 ± 0.0001^{aC}	1.470 ± 0.0001^{aA}	**
3 kGy	1.469 ± 0.0001^{aB}	1.466 ± 0.0001^{aC}	1.470 ± 0.0001^{aA}	**
6 kGy	1.469 ± 0.0001^{aA}	1.466 ± 0.0001^{aB}	1.469 ± 0.0001^{bA}	**
9 kGy	1.469 ± 0.0001^{aA}	1.466 ± 0.0000^{aB}	1.469 ± 0.0001^{bA}	**
P-level	NS	NS	**	

^{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 $p<0.01$.

Table 3. Effect of gamma irradiation and storage period on color change of Peanut oil

Storage period/ (Months)	0	6	12	P-level
Treatments		**L**		
Control	97.06 ± 0.20^{aA}	89.46 ± 0.73^{aB}	87.68 ± 0.08^{aC}	**
3 kGy	93.35 ± 0.02^{dA}	90.00 ± 0.03^{aB}	87.37 ± 0.10^{aC}	**
6 kGy	95.04 ± 0.47^{cA}	86.52 ± 0.21^{bB}	84.03 ± 0.09^{bC}	**
9 kGy	95.69 ± 0.21^{bA}	86.24 ± 0.07^{bB}	87.49 ± 1.31^{aB}	**
P-level	**	**	**	
		a		
Control	3.57 ± 0.10^{aA}	1.31 ± 0.21^{cC}	1.68 ± 0.09^{cB}	**
3 kGy	3.21 ± 0.02^{bA}	3.44 ± 0.17^{aA}	1.52 ± 0.13^{cB}	**
6 kGy	3.64 ± 0.30^{aA}	2.21 ± 0.10^{bA}	2.33 ± 0.08^{bB}	**
9 kGy	3.82 ± 0.08^{aA}	2.44 ± 0.16^{bC}	3.21 ± 0.41^{aB}	**
P-level	**	**	**	
		b		
Control	35.79 ± 0.04^{bB}	30.55 ± 2.43^{bC}	47.63 ± 0.33^{aA}	**
3 kGy	24.79 ± 0.06^{dC}	28.88 ± 0.41^{bB}	47.31 ± 0.08^{aA}	**
6 kGy	36.39 ± 0.25^{aB}	34.32 ± 0.37^{aC}	46.28 ± 0.42^{bA}	**
9 kGy	29.85 ± 0.16^{cC}	$33.86\pm0.32a^{B}$	45.24 ± 0.93^{cA}	**
P-level	**	**	**	
		ΔE		
Control	64.29 ± 0.03^{cB}	71.44 ± 2.49^{abA}	59.37 ± 0.25^{cC}	**
3 KGY	75.50 ± 0.05^{aA}	73.13 ± 0.45^{aB}	59.50 ± 0.14^{cC}	**
6 KGY	63.81 ± 0.29^{dA}	68.52 ± 0.46^{cA}	61.44 ± 0.38^{bC}	**
9 KGY	70.29 ± 0.15^{bA}	69.16 ± 0.37^{bcA}	62.01 ± 0.33^{aC}	**
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 $p<0.01$.

was higher ($p<0.05$), and the b* value of oil extracted from peanut seeds irradiated with 6 kGy was lower ($p<0.05$) comparing with those values of oil extracted from non irradiated control samples of peanut seeds. In contrast of our results Maxis and Kontominans [37] reported no short term effect of gamma irradiation on the color of raw peanuts (up to 7 kGy). According to previous work, De Camargo et al., [38] reported that the color of IAC-Tatsu peanut cultivar was not affected by the short term effects of gamma radiation at doses up to 15 kGy. However, IAC-Runner 886 cultivar was affected with respect to L* and Croma, which was indicated darkening of this cultivar.

Color development in peanut depends on certain of brownish-colored polymeric compound known as melanoidins. Melanoidins are water- insoluble, high molecular weight compounds formed via Millard browning products that correspond directly to color development in foods. Temperature, heating irradiation, pH, and moisture content play major roles in the formation of colored melanoidin compounds [5,26].

4. Conclusions

The overall physicochemical properties of peanut seed oil treated with 0, 3, 6 and 9 kGy and stored for 0 and12 months were determined. It was found that, for all analyzed samples, the acid value ranged from 1.44 to 2.36 mg KOH g^{-1} oil, peroxide value ranged from 1.04 to 1.35 meq g O_2 kg^{-1} oil of oil, iodine value ranged from 95.24 to 98.60 g iodine 100 g^{-1} oil, saponification value ranged from 190.54 to 195.72 g KOH g^{-1} oil, and Refractive index 1.469 to 1.470, These falls within the recommended codex for edible peanut oils (maximum acid value of 10 mg KOH g^{-1} oil, maximum peroxide level of 10 mg KOH g^{-1} oil, peroxide value of 10 mequiv. g O_2 kg^{-1} of oil, iodine value ranged from 86 to 107 g iodine 100 g^{-1} oil, saponification value ranged from 187 to 196 g KOH g^{-1} oil, and Refractive index 1.460 to 1.470.

Acknowledgements. The author wish to express his deep appreciation to the Director General of the Atomic Energy Commission of Syria and the staff of the division of food irradiation.

Compliance with Ethics Requirements. Author declares that he respect the journal's ethics requirements. Author declares that he have no conflict of interest and all procedures involving human or animal subjects (if exist) respect the specific regulation and standards.

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