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ORIGINAL ARTICLE

Microbial, Chemical and Sensorial Properties of Irradiated Sunflower (*Helianthus annuus* L.) Seeds

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Background: Oil seeds are among the major food commodities that can be affected by microorganisms, which are produced by a particular type of mold. Ionizing radiations are also used to reduce pathogen propagation when trading these products.

Methods: To investigate the effect of gamma irradiation and storage on quality of shelf-life of sunflower seed, samples of the seeds obtained from the market have been irradiated under 3, 6, and 9 kGy of gamma radiation and stored for 12 months.

Results: The results indicate that, all used doses of gamma irradiation had no significant ($p<0.05$) effect on moisture, ash and total sugar, while 6 kGy and 9 kGy had a significant ($p<0.05$) effect on protein, reducing sugar and oil content of sunflower oil. Along with the increase in the dose of irradiation, both bacterial and fungal count of the samples reduced to the undetectable limit after irradiation with 3 and 9 kGy respectively. Both total acidity and total volatile basic nitrogen increased significantly ($p<0.05$) with increasing the dose of irradiation and the storage time. Sensory evaluation showed that texture, flavour and texture were not affected significantly ($p<0.05$) by irradiation, while colour parameter was increased significantly ($p<0.05$) by irradiation.

Conclusion: Gamma irradiation could arrest microorganisms contamination of sunflower seeds, while maintaining the quality, as judged from proximate constituents, chemical properties and sensory evaluation.

Key words: Gamma irradiation; Microbial load; Proximate compositions; Sensorial properties; Sunflower seeds

Sunflower (*Helianthus annuus* L.) as an oilseed, is one of the four major annual oilseed crops produced in the word. The seed was often pounded into flour and used in cakes, mush, and bread. This list excluded sunflower seed and oil, thereby making it a popular food (Bensmira *et al*., 2007, Al-Bachir and Othman, 2018/b).

Oilseeds are dried after harvesting and can be stored for a long time before being processed. Appropriate humidity and moisture is required during storage to prevent spoilage and maintain mechanical stability of the seed, with a moisture content target of 7.5% (McKevith, 2005; Khalil and Al-Bachir, 2019). Storage of sunflower seeds under inadequate conditions may lead to growth of microorganisms, dry matter losses, moisture increase and high levels of free fatty acid in the seeds (Braghini *et al.,* 2009; Al-Bachir and Othman, 2018/b). However almost 25% of this kind of agricultural products would mildew suffer insect infestation or microbial contamination before consume (Junjie *et al.,* 2013). Oilseeds are among the major food commodities that can be affected by mycotoxins, which are produced by a particular type of mold (McKevith, 2005).

The food industry has become increasingly interested in developing novel food decontamination technologies to replace conventional methods such as heat or chemical additives, as these processes are incapable to complete elimination of contamination microorganisms (Maity *et al.,* 2011).

Food irradiation is a mechanized process of exposing food stuff to carefully controlled amount of energy in the form of high-speed particles/rays (Mahrous, 2007). Ionizing radiations are also used to sterilize some agricultural products in order to increase their conservation time or to reduce pathogen propagation when trading these products within the same country or from country to country (Melki and Salami, 2008; Al-Bachir, 2004; AL-Bachir, 2015a; 2015b; AL-Bachir and Al-Adawi, 2015; Khalil and Al-Bachir, 2019). To date, there is no major report stating the characterization and the use of gamma irradiation as physical process to improve the storability of oil seed produced under Syrian conditions. Thus, the aim of the present investigation was to study the effect of gamma radiation on the quality and safety of oilseeds, namely sunflower seeds as well as the inactivation of some microorganism responsible for spoilage and several outbreak around the world.

MATERIALS AND METHODS

Ten kilogram seeds of cultivated sunflower produced in Syria were purchased from local supermarkets and special shops in Damascus, Syria. Then sunflower seeds were weighed as in the sampling plan and transferred into polyethylene pouches for irradiation. Each pouch of sunflower seeds (250 g) was considered as a replicate. The samples were then divided into four groups: group 1 (control) and groups 2, 3 and 4 were irradiated with 3, 6 and 9 kGy of gamma irradiation.

Treatments and analysis performed

Samples from sunflower seeds were exposed to gamma radiation in a ^{60}CO package irradiator. Irradiation was carried out in the stationary mode of operation with the possibility of varying dose rate (10.846 to 3.921 kG h^{-1}) depending on the location and the distance from the source (10 to 40 cm). The samples were irradiated at place with a dose rate of 7.775 kGy h^{-1}. The irradiations were carried out at room temperature and atmospheric pressure. The absorbed dose was determined using alcoholic chlorobenzene dosimeter (Al-Bachir, 2004). The irradiated and control seed samples were stored for 12 months at room temperature 18-25°C under relative humidity (RH) of 50-70%. Microbiological and chemical analyses were performed on control and treated samples immediately after irradiation, and after 6 and 12 months of storage. Sensory evaluation were done within two days of irradiation.

Microbiological analysis

Microbial load was determined using standard spread plate method (AOAC, 2010). The product of sunflower seeds (10 g) was homogenized with 90 ml of sterile physiological water (9 g NaCl L^{-1}). The homogenate, then serially diluted and appropriate dilutions were plated on agar plate counts (APCs) (Oxoid, CM 325, UK) for total bacteria counts (30°C, 48 h) and Dichloran Rose-Bengal Chloramphenicol Agar

(DRBC) (Merck, 1.00466, Germany) for fungus (25oC, 5 days). Next, microbial populations were enumerated and results expressed as log CFU (colon forming units) g^{-1}.

Chemical analysis

Proximate analysis of sunflower seed moisture, ash, crude protein (micro-Kjeldahl), and fat (oil) (Soxhlet) content were determined using the methods described by AOAC (AOAC, 2010). Total sugar was estimated using Anthrone indicator method by measuring the absorbance at 620 nm with a T70 UV/VIS Spectrophotometer, (PG Instrument Ltd). The reducing sugars was estimated by iodometric determination of the unreduced copper remaining after reaction, and the concentration of reducing sugars were expressed as g glucose 100 g^{-1} powders (AOAC, 2010). pH values of the solutions of sunflower seeds were determined using an HI 8521 pH meter (Hanna Instruments, Woonsocket, RI, USA). The total acidity was obtained by a direct titration with (0.1 N) NaOH and phenolphthalein as an indicator. The total acidity was calculated as ml of (0.1 N) NaOH = 0.0090 g lactic acid (AOAC, 2010). Total volatile basic nitrogen in the sample in term of mg VBN kg^{-1} sunflower seeds (ppm) was determined (Al-Bachir, 2004).

Sensory evaluation

Sensory evaluation (consumer analysis) was carried out by 20 member untrained panel. Approximately 20 g of whole sunflower seeds were placed in small glasses coded containers. Panelists were served a set of four treated samples (0, 3, 6, and 9 kGy) and they were instructed to consume the whole sample and rinse mouth with sparkling water (room temperature), in between sample evaluation. Sensorial attributes evaluated included colour, texture, odour and taste was assessed as the measurement of the acceptability of the product by the consumer, using 5-point structured scales, 5 being the best and 1 the worst quality (Al-Bachir, 2004).

Statistical analysis

Three replicates of each treatment were used and all the assays were carried out in triplicate. The results were expressed as mean value and standard division (SD). 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: $p<0.05$*, $p<0.01$** (Snedecor and Cochran,1988).

RESULTS AND DISCUSSION

Proximate composition of sunflower seeds

Table 1 shows the mean values of proximate composition of sunflower seed reported as mean value of four irradiation doses (0, 3, 6 and 9 kGy) over three different storage times (0, 6 and 12 months).

Moisture: The value of moisture content (3.89%) of control samples of sunflower seeds was lower than that of average (5.4%) of those reported for different spices and variety of sun flower produced in different area of the world (Robertsone, *et al.,* 1971). It is worth noting that, high moisture reduces the shelf-life of the foods while low moisture content keeps the spoilage at insignificant level (Ogungbenle and Omosola, 2015). Increases in the moisture content is one of the main reasons for increasing the fungal growth and as a results of aflatoxin production (Khalil and Al-Bachir, 2019).

Ash: The total ash content of the sunflower seeds in the present study (3.30%) was close similar to those of sesame (3.8%), cotton seed (4%), sunflower seed and pumpkin seeds (4.41%) and soybean (5.0%) (Abd El-Aziz *et al.,* 2011; Kamel *et al.,* 1982).

Protein: The protein content found in this study (23.44%) was in good agreement with the average protein content (19.8 - 22.7%) of those reported for different variety of sunflower produced in different area of the world (McKevith, 2005).

Oil: The oil content found in the present study (48.95%) was higher than that of average oil content (39.5%) reported for Iranian sunflower (Kouchebagh *et al.,* 2014), and lower than that of oil yield representing 60-80% of the amount industrially obtained from cultivated sunflower seed varieties (Perez *et al.,* 2007).

Effect of irradiation and storage on proximate composition of sunflower seeds

Regarding the irradiation exposure, gamma irradiation at 3 kGy, 6 kGy and 9 kGy had no significant ($p<0.05$) effect on moisture, ash and total sugar, while 6

kGy and 9 kGy had a significant ($p<0.05$) effect on protein, reducing sugar and oil content of sunflower seeds (Table 1). In agreement with our present results, Yakoob et al. (2010) determined that gamma irradiation (2-10 kGy) did not affect the lipid, protein, fiber and ash content of either sunflower nor maize seeds significantly ($p<0.05$). Irradiation treatment at 5 kGy and 10 kGy had no significant effect on protein, fat and carbohydrate content ($p>0.05$) of African oil bean seeds (Enujiugha *et al.,* 2012). In general, there are no appreciable differences in proximate composition (crude fat, ash and total sugar) of green faba bean kernel samples irradiated with 0, 1, 5 and 10 kGy. (Khalil and Al-Bachir, 2019).

In the present study, a significant ($p<0.05$) decrease in the reducing sugar was observed in irradiated and stored sunflower seeds (Table 1). This could be due to non-enzymatic browning reaction, involving reducing sugars, that occurred as a result of radiation processing, and storage of peanut seeds (Chawla *et al.,* 2009). Nevertheless, chemical changes in proteins caused by gamma irradiation include fragmentation, cross-linking, aggregation and oxidation by oxygen radicals that are generated in the radiolysis of water (Afify *et al.,* 2011; Tresina *et al.,* 2017). The change of the proximate composition of sunflower seeds during storage are shown in Table 1. Differences in total protein, fat, ash and reducing sugar contents between the storage period was statistically significant ($p<0.05$), while differences in moisture contents was not statistically significant. After 12 months of storage, the total fat and ash increased ($p<0.05$), while the total protein and reducing sugar decreased ($p<0.05$).

Effect of gamma irradiation and storage time on chemical properties of sunflower seeds

Total acidity and pH value: Results in Table 2 showed that, immediately after irradiation, the total acidity (expressed as lactic acid) was highest in sunflower seed samples irradiated with 6 kGy (0.99%) followed by samples irradiated with 9 kGy (0.93%) and 3 kGy (0.86%) and was lowest in the control sample (0.78%). This is in agreement with the study of Khalil and Al-Bachir, (2019) who found that irradiation of faba bean increased the total acidity. The low free fatty acids in sunflower seeds in the present study and slight differences between the treatments could be attributed to the low moisture contents of the seeds. In the literature, it was mentioned that especially the hydroxyl radicals formed after irradiation of the foods that have a high water content may trigger fat oxidation and change the composition of fatty acid compositely same reactions occur slower in dry foods (Golge and Ova, 2008). Total acidity percentage increased significantly ($p<0.05$) during storage period of 12 months in both non-irradiated control and irradiated with 9 kGy sunflower seed samples. Al-Bachir (2015b) pointed out that as the storage time increased, total acidity of irradiated and non-irradiated almonds increased. The acid values of the oil seeds indicate the total acidity as contributed by the fatty acids in the samples. Hydrolysis of glycerides to yield fatty acid occurs during storage (Mexis and Kontominas, 2010; Al-Bachir 2017).

The effect of various levels of gamma irradiation and storage time on pH value is shown in Table 2. The pH value of non-irradiated control samples of sunflower seeds was 6.84. The higher doses of gamma irradiation (6 and 9 kGy) decreased significantly ($p<0.05$) the pH value of sunflower seeds.

The decrease in pH value in samples irradiated with 6 and 9 kGy was probably due to an increased amount of organic acids released during irradiation treatment.

Total volatile basic nitrogen (TVBN): The effect of various levels of gamma irradiation and storage time on total volatile basic nitrogen (VBN) contents of sunflower seeds were compared. As seen in Table 2, the mean value of VBN of the non-irradiated control sample of sunflower seed samples was 293.76 ppm. Irradiation of sunflower seed samples had no significant effect ($p<0.05$) on their VBN content when the analysis was carried out immediately after irradiation. While, the value of VBN of irradiated sunflower seeds with 6 and 9 kGy doses of gamma irradiation were significantly ($p<0.05$) higher than those of the control when the analysis was carried out after 12 months of storage (Table 2). Previous observations in walnut (Al-Bachir, 2004), pistachio nut (Al-Bachir, 2015a), and almond nut (Al-Bachir, 2015b) indicate that gamma irradiation had an effect on VBN. During storage of sunflower seeds at

ambient temperature, the VBN contents increased significantly in case of non-irradiated and irradiation samples. After 12 months of storage, the VBN contents were 299.59, 298.32, 306.19 and 314.32 ppm for sunflower seeds treated with 0, 3, 6 and 9, respectively. The VBN is related to protein breakdown (Al-Bachir and Othman, 2018/a) and the observed increases through the storage periods may be attributed to the formation of ammonia or other basic compounds due to microbial activity (Khalil and Al-Bachir, 2019; Badr, 2004).

It appears that there is a disagreement between various authors on the chemical properties as a consequence of irradiation and storage which can be attributed to the different experimental conditions and samples. The results of our work are also difficult to be compared with the aforementioned studies since it was conducted under different experimental conditions (room temperature) and on different samples (sunflower seeds).

Effect of irradiation and storage time on microbial load of sunflower seed

The effect of different doses (3, 6 and 9 kGy) of gamma irradiation in the microbial load infection of sun flower seeds by bacteria and fungi are shown in Table 3. Total bacterial count and total fungal count of non-irradiated (control) sample were 2.21 and 3.35 log cfu g^{-1}, respectively (cfu= colony forming unit). The radiation doses of 3, 6 and 9 kGy reduced the bacterial and fungal count to below detection level when the analysis was carried out after day zero of storage. During storage of sunflower seed at ambient temperature, the bacterial and fungal count increased significantly in case of non-irradiated and irradiation samples because of the growth of surviving bacteria and fungi during irradiation. After 12 months of storage, and for control samples of sunflower seeds, the total bacterial and fungal counts increased from 2,21 to 2.80 log10 cfu g^{-1} and from 3,35 to 4.97 log10 cfu g^{-1}, respectively. Irradiation was found to cause significant ($p<0.05$) reduction in microbial load proportionate to dose delivered. Only the doses of 9 kGy reduced the initial bacterial load to below detection level when analysis was carried out after 12 months of storage. The results in sunflower seeds are accordance with early reports about reduction of different microorganisms, which is followed by re-growth of microorganisms on irradiated vegetables (Trigo *et al.,* 2009), and walnut (Al-Bachir, 2004).

Several authors have investigated the effects of gamma irradiation on bacterial and fungal growth on different products. However, the different laboratory conditions used in the experiments impair comparison of the results, including the number of spores, humidity, temperature radiation doses, and exposure or not to light (Braghini *et al.,* 2009; Al-Bachir, 2004; Al-Bachir, 2015a; Al-Bachir, 2015b; Al-Bachir and Al-Adawi, 2015; Khalil and Al-Bachir, 2019; Aziz and Mahrous, 2004).

The effect of irradiation may be beneficial or causing damage, depending on the characteristics of radiation (power, intensity, distance and exposure times) and on the characters of the biological material to be subject to the treatment (Paez *et al.,* 2011).

Effect of irradiation on sensory quality of sunflower seed

The acceptance scores of the effect of gamma irradiation treatments in sunflower seeds are shown in Table 4. Taste, flavor and texture were not affected by irradiation ($p<0.05$). On contrary, color of sunflower seeds increased ($p<0.05$) in samples irradiated with 9 kGy. Un-treated control samples of sunflower seeds had the lowest score for all attributed (3.44, 3.26, 3. 57 and 3.22 for taste, flavor, color and texture respectively), whereas the highest lowest score for most attributes were observed with 9 kGy (3.74, 3.74, 4.30 and 4.04 for taste, flavor, color and texture respectively). The oxidation of oils and fats is one of the main causes of the deterioration of the organoleptic and nutritional characteristics of foodstuffs, due to the development of rancidity (Ghosh *et al.,* 2014). It's obvious that gamma irradiation of lipid induces the production of free radical, which is responsible for the alteration of foods nutritional and sensorial characteristics (Al-Bachir and Koudsi, 2017). Chemat et al. (2004) reported that the peroxide value of sunflower oil was increased when it was treated by ultrasound wave, and its flavor and composition were deteriorated.

The increase in color of sunflower seed samples irradiated with 9 kGy might be attributed to irradiation induced non-enzymatic browning or Millard reaction due

to radiation treatment of the investigated sunflower seeds. These results agree with Hania and El-Niely (2013) and Al-Bachir and Othman (2019). who reported that the increase in yellow color of legume and sesame seeds with irradiation may be an indication to the occurrence of Millard reaction.

Table 1. Effect of gamma irradiation and storage period on moisture, ash, protein, total sugar, reducing sugar and fat contents (%) of Sunflower seed.

Treatment	Control	3 KGY	6 KGY	9 KGY	P-level
Storage period/(Months)					
		Moisture (%)			
0	3.89±0.26^{aB}	4.12±0.24^{aAB}	4.08±0.13^{aB}	4.21±0.23^{aA}	**NS**
6	4.23±0.09^{bA}	4.35±0.20^{bA}	4.75±0.18^{aA}	4.13±0.02^{bA}	**
12	3.98±0.01^{aAB}	3.91±0.12^{aB}	3.98±0.04^{aB}	4.03±0.08^{aA}	**NS**
P-level	**NS**	**NS**	**	**NS**	*
		Total protein (%)			
0	23.44±0.07^{bAB}	23.23±0.31^{bcB}	23.78±0.05^{aA}	23.13±0.06^{cB}	*
6	23.69±0.20^{bA}	23.92±0.12^{aA}	23.76±0.05^{abA}	23.11±1.51^{cB}	**
12	23.20±0.11^{cB}	23.33±0.06^{bcB}	23.50±0.09^{aB}	23.38±0.08^{abA}	
P-level	*	**	**	**	
		Total fat (%)			
0	48.95±0.08^{bC}	48.35±1.09^{bB}	54.48±0.85^{aA}	54.56±0.21^{aA}	**
6	52.44±1.30^{aA}	52.19±0.84^{aA}	51.95±0.69^{aB}	51.16±1.32^{aB}	**NS**
12	50.82±0.19^{bB}	51.42±0.14^{aA}	51.69±0.11^{aB}	51.50±0.17^{aB}	**
P-level	**	**	**	**	
		Ash (%)			
0	3.30±0.49^{aB}	3.39±0.38^{aB}	3.43±0.12^{aB}	3.38±0.^{19aB}	**NS**
6	3.18±0.02^{bB}	3.43±0.13^{aB}	3.23±0.10^{bC}	3.41±0.10^{aB}	*
12	4.18±0.01^{aA}	4.17±0.01^{aA}	4.18±0.04^{aA}	4.16±0.04^{aA}	**NS**
P-level	**	**	**	**	
		Total sugar (%)			
0	11.94±0.16^{aA}	11.81±0.32^{aA}	11.71±0.30^{aA}	12.11±0.26^{aA}	**NS**
6	10.02±1.98^{aA}	12.32±0.60^{aB}	10.96±1.63^{aA}	13.11±1.91^{aA}	**NS**
12	12.10±0.34^{bA}	12.32±0.60^{bA}	11.65±0.45^{bA}	13.80±0.89^{aA}	*
P-level		**NS**	**NS**	**NS**	
		Reducing sugar (%)			
0	1.01±0.05^{aA}	0.80±0.06^{bA}	0.85±0.11^{bA}	0.85±0.04^{bA}	*
6	0.52±0.02^{bC}	0.58±0.08^{abB}	0.61±0.02^{aB}	0.62±0.02^{aB}	*
12	0.63±0.03^{aB}	0.64±0.02^{aB}	0.62±0.01^{aB}	0.63±0.01^{aB}	**NS**
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.

Table 2. Effect of gamma irradiation and storage period on total acidity (% Lactic acid), PH value and volatile basic nitrogen (VBN)(P.P.M) of Sunflower seed.

Treatment	Control	3 KGY	6 KGY	9 KGY	P-level
Storage period (Months)					
		Total acidity (% Lactic acid)			
0	0.78±0.09^{cB}	0.86±0.07^{bcB}	0.99±0.06^{aA}	0.93±0.05^{abB}	*
6	0.87±0.05^{aAB}	0.83±0.08^{aB}	0.83±0.07^{aB}	0.91±0.04^{aB}	NS
12	0.99±0.04^{aA}	0.97±0.03^{aA}	0.98±0.02^{aA}	1.01±0.02^{aA}	NS
P-level	*	NS	*	*	
		PH value			
0	6.84±0.04^{aA}	6.85±0.02^{aA}	6.80±0.02^{aA}	6.80±0.04^{aA}	NS
6	6.79±0.01^{aB}	6.82±0.02^{aA}	6.78±0.03^{aA}	6.69±0.04^{bB}	**
12	6.82±0.03^{aAB}	6.84±0.03^{aA}	6.81±0.03^{aA}	6.84±0.03^{aA}	NS
P-level	NS	NS	NS	**	
		Volatile basic nitrogen (ppm)			
0	293.76±3.32^{aA}	288.19±9.58^{aA}	290.87±6.00^{aB}	289.50±4.05^{aB}	NS
6	277.41±5.77^{cB}	286.11±5.86^{bcA}	291.17±3.18^{abB}	296.23±4.20^{aB}	**
12	299.59±2.63^{cA}	298.32±1.56^{cA}	306.19±2.84^{bA}	314.32±3.00^{aA}	**
P-level	**	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 Total bacterial (log10 cfu g) and fungal (log10 spores /g) count of sunflower seed.

Treatment	Control	3 KGY	6 KGY	9 KGY	P-level
Storage period/(Months)					
		Total bacterial count (log_{10} cfu g)			
0	2.21±0.07^{aC}	>1^{bC}	>1^{bB}	>1^{bA}	**
6	2.70±0.05^{aB}	2.14±0.04^{bB}	>1^{cB}	>1^{cB}	**
12	2.80±0.04^{aA}	2.33±0.03^{bA}	2.06±0.04^{cA}	>1^{dA}	**
P-level	**	**	**	-	
		Fungal count (log_{10} spores g)			
0	3.35±0.04^{aC}	>1^{bC}	>1^{bC}	>1^{bC}	**
6	4.14±0.22^{aB}	2.81±0.02^{bB}	2.60±0.04^{bB}	2.31±0.09^{cB}	**
12	4.97±0.03^{aA}	3.07±0.03^{bA}	2.81±0.07^{cA}	2.52±0.09^{dA}	**
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.

Table 4. Effect of gamma irradiation and storage period on the taste, texture, color and flavor of Sunflower seed.

Treatment	Control	3 KGY	6 KGY	9 KGY	P-level
Taste	3.44±1.31^{a}	3.83±1.07^{a}	3.65±1.07^{a}	3.74±0.96^{a}	NS
Flavor	3.26±1.29^{a}	3.61±0.89^{a}	3.65±0.78^{a}	3.74±0.92^{a}	NS
Color	3.57±1.34^{bc}	3.39±0.78^{c}	4.04±0.93^{ab}	4.30±0.70^{a}	**
Texture	3.22±1.24^{b}	3.74±0.92^{ab}	3.74±1.10^{ab}	4.04±1.11^{a}	NS

^{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.

CONCLUSION

Irradiation of full-fat sunflower seeds irradiated at a dose level of 3, 6 and 9 kGy reduced the bacteria as well as fungi in the seeds, and retained their normal levels of moisture, ash, crud protein, total sugar, reducing sugar and crude fat. These dose levels did not affect significantly ($p<0.05$) the chemical (total acidity, pH value and total volatile basic nitrogen) and sensorial (taste, flavor, color and texture) properties of sunflower seeds.

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CONFLICTS OF INTEREST

Authors declared no potential conflict of interest

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