ACTA SCIENTIARUM POLONORUM
Acta Sci. Pol. Technol. Aliment. 15(2) 2016, 171–179
www.food.actapol.net pISSN 1644-0730 eISSN 1889-9594 DOI: 10.17306/J.AFS.2016.2.17

ORIGINAL PAPER

Received: 2.12.2015
Accepted: 10.02.2016

EVALUATION THE EFFECT OF GAMMA IRRADIATION ON MICROBIAL, CHEMICAL AND SENSORIAL PROPERTIES OF PEANUT (*ARACHIS HYPOGAEA* L.) SEEDS

Mahfouz Al-Bachir✉

Radiation Technology Department, Atomic Energy Commission of Syria
P.O. Box 6091, Damascus, **Syria**

ABSTRACT

Background. The aim of the present study was to evaluate the possibility to apply gamma radiation treatment for decontaminating and assuring the quality of peanut seeds.
Material and methods. The radiation processing was carried out at dose levels of 3, 6 and 9 kGy. The irradiated and non-irradiated (control) samples were stored at room temperature for 12 months, and analyzed for microbial load, proximate composition, sensorial acceptance and chemical properties.
Results. The results indicated that gamma irradiation treatment significantly ($p < 0.05$) reduced microbial load and enhanced the safety of the irradiated samples. The irradiated samples were also acceptable sensorically. The total acidity and total volatile nitrogen (TVBN) contents increased with the increase of radiation dose. Furthermore, in general, no substantial change in proximate constituents was observed amongst the samples. No significant ($p > 0.05$) differences in the taste, flavor, color and texture score were observed among treatments (0, 3, 6 and 9 kGy).
Conclusion. Irradiation protected again bacterial and fungal growth and retained the nutritional components of samples during long-term storage.

Key words: peanut, gamma irradiation, chemical composition, sensory evaluation, assessment of microbiological, storage

INTRODUCTION

The peanut (*Arachis hypogaea* L.) is an important source of protein in developing and developed countries (Yoshida et al., 2005). A lot of peanuts may be consumed raw, roasted, pureed, or in a variety of other processed forms (Taha et al., 2012). Peanuts have attracted a great deal of attention as a functional food (Fransisco and Resurrection, 2008). Raw seeds of peanut can be stored without lipid oxidation for over one year if they remain whole and intact. On the other hand, if the peanuts are dry-roasted to inactivate enzymes, they are oxidatively stable (Frankel, 2005; Jittrepotch et al., 2010). Microbiological contamination of seeds in storage has resulted in major socio-economic problems throughout the world. The quality of stored seeds can deteriorate due to infestation (Francisco and Usberti, 2008), and the contamination of peanuts with mycotoxins, particularly aflatoxins, is a worldwide problem that affects both food safety and agricultural economies (Dorner, 2008). However, improved agricultural practices and better storage and transportation facilities have reduced the toxigenic mould growth in seeds used for human consumption (Astoreca et al., 2007).

✉ascientific@aec.org.sy

Various methods of preservation have been applied to arrest growth of microorganisms including moulds in foods, such as fumigation and heat treatments, but none of these methods offers complete control of microorganisms (Paez et al., 2011). Ionizing radiation is one of the methods applied to decontaminate microorganisms in different food commodities (Al-Bachir, 2004; Al-Bachir, 2015a; Al-Bachir, 2015b; Al-Bachir and Al-Adawi, 2015; Aziz et al., 2007).

Although peanut seeds are nutritionally important in some parts of the world, including Syria, no reports were documented in the literature about the microbial, physico-chemical and sensorial characteristics concerning the composition of irradiated, non-irradiated or marketed local cultivated peanut seeds in Syria. However, there are many publications produced by researchers from other countries on the irradiation of peanuts (Chiou et al., 1990; De Camargo et al., 2012; Mexis and Kontominas, 2009; Seda et al., 2001).

Due to the differences among the species and/or varieties of peanuts grown in different areas of the world, the present study was undertaken to determine the composition of the whole seed, and the effect of gamma irradiation in microbial, chemical and sensorial properties of peanut seeds grown in Syria.

MATERIAL AND METHODS

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

Treatment and analysis performed

Samples from peanut seeds were exposed to gamma radiation in a ^{60}CO package irradiator (ROBO, Russia). Irradiation was carried out in the stationary mode of operation with the possibility of varying the 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 in a place with a dose rate of 7.775 kGy·h^{-1}. The irradiations were carried out at room temperature and atmospheric pressure. The dose absorbed was determined using an ethanolic chlorobenzene dosimeter (Al-Bachir, 2004). The irradiated and control seed samples were stored for 12 months at room temperature 18–25°C under a 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 was made within two days of irradiation.

Microbiological analysis

The microbial load was determined using the standard spread plate method (AOAC, 2010). The peanut seed product (10 g) was homogenized with 90 ml of sterile physiological saline (9 g NaCl·l^{-1}). The homogenate was 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 (25°C, 5 days). After plating, the colony forming units (CFUs) were counted, and microbial counts were expressed by means of log CFU.

Chemical analysis

Proximate analysis of the peanut seed moisture, crude protein (micro-Kjeldahl, % protein = %N × 5.46), fat (oil) (Soxhlet) and ash contents were determined using the methods described by AOAC (2010). Total sugar was estimated using the Anthrone indicator method by measuring the absorbance at 620 nm with a T70 UV/VIS Spectrophotometer (PG Instrument Ltd). The reducing sugars were estimated by iodometric determination of the unreduced copper remaining after reaction, and the concentration of reducing sugars was expressed as g glucose/100 g powders (AOAC, 2010). The pH values of the solutions of peanut seeds were determined using an HI 8521 pH meter (Hanna Instruments, Woonsocket, RI, USA). The total acidity was obtained by direct titration with (0.1 mol·l^{-1}) NaOH and phenolphthalein as an indicator. The total acidity was calculated as ml of (0.1 mol·l^{-1}) NaOH = 0.0090 g lactic acid (AOAC, 2010). Total volatile basic nitrogen in the sample in terms of mg VBN·kg^{-1} peanut seeds [ppm] was determined (Al-Bachir, 2004).

Sensory evaluation

Sensory evaluation (consumer analysis) was carried out by a 20-member untrained panel. Approximately 20 g of whole peanut seeds were placed in small glass 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 their mouths with sparkling water (room temperature) in between sample evaluation. Sensorial attributes included color, texture, odor and taste were assessed as the acceptability of the product by the consumer, using 5-poit 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 a mean value and standard deviation (SD). The data were subjected to the analysis of variance test (ANOVA) using the SUPERANOVA computer package (Abacus Concepts Inc, Berkeley, CA, USA; 1998). A p value of less than 0.05 was considered statistically significant. The degree of significance was denoted as: $p < 0.05$, $p < 0.01$ (Snedecor and Cochran, 1988).

RESULTS

Peanut seed characteristics

The results of chemical composition analysis of irradiated and non-irradiated peanut seeds are presented in Table 1. The non-irradiated control peanut seeds contained 2.02 ±0.28% of moisture and were safe for a long storage period without spoilage, because it is generally the case that seeds with such as low moisture content are not highly susceptible to microorganism attack (Ajayi et al., 2006). In general, the following are admitted as maximum values for good peanut conservation are: peanut humidity 9%, relative humidity 70% and environmental temperature of 20°C; fungal development and spoilage of peanut start above these values (Astoreca et al., 2009).

The protein content (22.23%) reported in this study (Table 1) is found to be comparable to that of other oilseeds, e.g. cashew nut (22.10%; Aremu and Akinwumi, 2014), walnuts (22.85%; Al-Bachir, 2004), pistachio kernels (21.47%; Al-Bachir, 2015a) and almond kernels (17.92%; Al-Bachir, 2015b).

The ash content found in this study (2.47%; Table 1) was a little higher than that reported for peeled (2.11%), in-shell (2.12%) and blanched (1.90%) peanut seeds (De Camargo et al., 2012).

The fat content of the peanut seed was found to be 47.80 ±2.80% (Table 1). This value is in agreement with those indicated by De Camargo et al. (2012) for peeled (46.92%), in-shell (46.48%) and blanched (47.33%) peanut seeds. There is a huge variation reported in the literature concerning the lipid percentage (Davis et al., 2008). It has been claimed that such differences in fat content can be attributed to genetic diversity and climate conditions (Stevenson et al., 2007).

The total sugar content of peanut seeds was calculated to be 11.03 ±0.78%, and Syrian cultivated peanut seeds contain 0.53 ±0.02% reducing sugar (Table 1).

Thus, the results of our present study on the proximate composition of peanut seeds are in agreement with the hypothesis put forward by other authors that the approximate composition variation of seeds after harvest is a direct function of the inital plant material and of the specific growing conditions, such as the climatic conditions or vegetative cycle, and is independent of the treatments applied post-harvest or the subsequent storage conditions (Sanchez-Bel et al., 2008).

Effect of irradiation and storage on proximate composition of peanut seeds

It is evident from Table 1 that there was non-significant effect of irradiation treatment on the macronutrient content of peanut seeds. Irradiation with 3, 6 and 9 kGy did not produce any significant ($p > 0.05$) effect on the crude protein, crude oil and total sugar content of peanut seeds. The non-significant effects of the applied radiation doses used in this study can be attributed to the relatively limited water content of peanut seeds. The moisture content of peanut seed samples in this study was low (2.02%) and did not produce enough of the water that free radicals needed to induce significant changes in the gross composition of the seeds studied. It was therefore expected that crude protein, crude fat, ash, and total sugar would remain largely unaltered through the assay for all the treatments applied. The moisture content of peanut seeds

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

Storage period months	Treatment				
	control	3 kGy	6 kGy	9 kGy	*p*-level
			Moisture, %		
0	2.02 ±0.28^{bC}	2.22 ±0.08^{abC}	2.42 ±0.09^{aB}	2.21 ±0.21^{abC}	NS
6	3.18 ±0.20^{aB}	3.16 ±0.17^{aB}	3.19 ±0.20^{aA}	3.29 ±0.02^{aB}	NS
12	3.91 ±0.14^{aA}	3.70 ±0.13^{abA}	3.22 ±0.07^{cA}	3.64 ±0.11^{bA}	**
p-level		**	**	**	
			Total protein, %		
0	22.23 ±0.11^{aB}	22.06 ±0.18^{aB}	22.27 ±0.23^{aB}	21.32 ±1.15^{aB}	NS
6	23.63 ±0.34^{aA}	23.62 ±0.16^{aA}	23.46 ±0.17^{aA}	23.96 ±0.37^{aA}	NS
12	23.58 ±0.22^{aA}	23.42 ±0.09^{aA}	23.30 ±0.03^{aA}	23.17 ±0.49^{aA}	NS
p-level	**	**	**	*	
			Total fat, %		
0	47.80 ±2.80^{aA}	44.85 ±0.41^{aB}	46.39 ±1.35^{aA}	44.89 ±1.50^{aA}	NS
6	48.81 ±0.99^{aA}	48.26 ±0.22^{abA}	47.50 ±0.25^{bA}	47.70 ±0.62^{abA}	NS
12	46.18 ±1.45^{aA}	45.49 ±0.97^{aB}	46.49 ±2.83^{aA}	47.65 ±2.05^{aA}	NS
p-level	NS	**	NS	NS	
			Ash, %		
0	2.47 ±0.15^{aA}	2.35 ±0.19^{aA}	2.23 ±0.09^{aA}	2.40 ±0.11^{aA}	**
6	2.41 ±0.20^{aA}	2.29 ±0.05^{aA}	2.31 ±0.02^{aA}	2.52 ±0.20^{aA}	NS
12	2.38 ±0.18^{aA}	2.44 ±0.23^{aA}	2.23 ±0.09^{bA}	2.65 ±0.11^{aA}	NS
p-level	NS	NS	NS	NS	
			Total sugar, %		
0	11.03 ±0.78^{bA}	11.09 ±0.26^{bB}	12.20 ±0.57^{aB}	12.02 ±0.46^{abB}	NS
6	11.13 ±0.57^{bA}	11.50 ±0.26^{bB}	11.70 ±0.39^{bB}	12.63 ±0.29^{aAB}	**
12	11.25 ±0.76^{bA}	12.92 ±0.37^{aA}	13.07 ±0.27^{aA}	12.72 ±0.05^{aB}	**
p-level	NS	**	*	NS	
			Reducing sugar, %		
0	0.53 ±0.02^{cB}	0.63 ±0.02^{aB}	0.57 ±0.04^{bcB}	0.61 ±0.02^{abB}	*
6	0.68 ±0.07^{bA}	0.74 ±0.04^{bA}	0.97 ±0.06^{aA}	1.03 ±0.05^{aA}	**
12	0.41 ±0.04^{bC}	0.41 ±0.01^{bC}	0.52 ±0.02^{aB}	0.52 ±0.01^{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.
* Significant at $p < 0.05$.
** Significant at $p < 0.01$.
NS – not significant.

in this study was not substantially affected by gamma irradiation. Similar findings showed that gamma irradiation had no real effect on the moisture content of oil seeds (Abd El-Aziz and Abde El-Kalek, 2011). The present findings are in close agreement with the data previously obtained by Hania and El-Niely (2013), who showed that irradiation of legume seeds at a dose of 10 kGy did not induce any significant changes in the chemical compositions. Moreover, gamma irradiation did not induce any change in the chemical compositions of groundnut (Seda et al., 2001), walnuts (Al-Bachir, 2004), pistachio (Al-Bachir, 2015a) and almond (Al-Bachir, 2015b). Extensive research has shown that protein did not exhibit significant losses during irradiation even at doses of over 10 kGy (Jan et al., 2012).

During storage (after 6 and 12 months), the moisture content increased significantly ($p < 0.01$) in both control and irradiated peanut seeds and this increase was higher in the control samples compared to irradiated ones.

Effect of gamma irradiation and storage time on chemical properties

Total acidity and pH value: The total acidity (% lactic acid) of peanut seeds as a function of irradiation dose and storage time is shown in Table 2. According to the research findings, if the dose of irradiation increases, total acidity percentage increases proportionally. At the beginning of the experiment, the total acidity level was 1.39%, 1.42%, 1.44% and 1.47% for peanut seeds treated with 0, 3, 6 and 9 kGy, respectively. It was found that the effect of irradiation exposure on the total acidity of samples was not statistically significant ($p > 0.05$) at the beginning of the experiment. After 6 months of storage, only 9 kGy significantly ($p < 0.01$) decreased the total acidity, while after 12 months of storage, both irradiation doses 6 and 9 kGy significantly ($p < 0.01$) increased the total acidity in peanut seeds. This finding is consistent with work carried out by other researchers who studied the effect of irradiation with doses up to 10 kGy on other oil seeds (black cumin seeds; Arici et al., 2007). However, on other hand, Wen et al. (2006) found no significant changes in pH and acidity following 4 and 8 kGy gamma irradiation in lucium fruit. Increases in irradiation doses of up to 10 kGy resulted in an increase in free fatty acid (FFA) levels. A dose-dependent decrease in the triacylglycerol content and concomitant increase in free fatty acids was observed after gamma irradiation of nutmeg (Niyas et al., 2003).

During storage for six months, the total acidity of peanut seed oil increased ($p < 0.01$) in non-irradiated control and those irradiated with 3 and 6 kGy samples.

Storage and irradiation treatment did not significantly ($p > 0.05$) affect the pH value of the peanut seed samples. Samples irradiated with 6 kGy had the highest pH value (6.76), whereas the lowest pH value (6.70) was observed for non-irradiated control samples of peanut seeds. After 12 months of storage, irradiated and non-irradiated peanut seeds exhibited a pH value which was slightly lower than that of unstored ones (day zero), but still significant ($p < 0.01$; Table 2)

Total volatile basic nitrogen (TVBN): As seen in Table 2, gamma irradiation doses and storage periods affected ($p < 0.01$) the total volatile basic nitrogen (TVBN) of peanut seeds significantly. The doses of gamma irradiation (3, 6 and 9 kGy) used significantly increased ($p < 0.01$) the TVBN in peanut seeds. Immediately after irradiation, the TVBN values reached 382.90, 393.97, 469.22 and 490.27 $mg \cdot kg^{-1}$ for peanut seed samples irradiated with 0, 3, 6 and 9 kGy, respectively. During storage, the TVBN of peanut seed decreased ($p < 0.01$) in all samples regardless of the irradiation dose. Our results related to the effect of gamma irradiation and storage time on TVBN are consistent with a previous report which also indicated that the TVBN of almonds increased due to irradiation doses and storage periods (Al-Bachir, 2015b). Gamma radiation (up to 10 kGy) and storage time (up to 6 months) increased oxidation compound production (De Camargo et al., 2012). Volatile secondary compounds such as aldehydes, ketones and alcohols have had their concentration increased in peanuts subjected to gamma radiation with doses up to 7.0 kGy (Mexis and Kontominas, 2009).

Effect of irradiation and storage time on microbial load

Table 3 reveals lower bacterial contamination (2.68 log 10 $cfu \cdot g^{-1}$) in peanut seeds than fungal (3.19 log 10 $cfu \cdot g^{-1}$). Exposure of peanut seeds to gamma irradiation produced a significant ($p < 0.01$) reduction in

Table 2. Effect of gamma irradiation and storage period on total acidity [% lactic acid], pH value and total volatile basic nitrogen [TVBN; ppm] of peanut seeds

Storage period months	Treatment				
	control	3 kGy	6 kGy	9 kGy	*p*-level
	Total acidity, % lactic acid				
0	1.39 ±0.03^{aB}	1.42 ±0.02^{aB}	1.44 ±0.04^{aB}	1.47 ±0.10^{aA}	NS
6	1.68 ±0.03^{abA}	1.76 ±0.15^{aA}	1.73 ±0.03^{aA}	1.53 ±0.13^{bA}	NS
12	1.28 ±0.13^{bB}	1.33 ±0.12^{bB}	1.40 ±0.04^{abB}	1.50 ±0.00^{aA}	**
p-level	**	**	**	NS	
	pH value				
0	6.70 ±0.07^{aA}	6.72 ±0.03^{aA}	6.76 ±0.02^{aA}	6.71 ±0.03^{aA}	NS
6	6.50 ±0.03^{aB}	6.45 ±0.05^{bC}	6.42 ±0.02^{bC}	6.46 ±0.02^{abC}	*
12	6.62 ±0.05^{aA}	6.58 ±0.04^{aB}	6.58 ±0.05^{aB}	6.58 ±0.01^{aB}	NS
p-level	**	**	**	**	
	Total volatile basic nitrogen, ppm				
0	382.90 ±20.79^{bA}	393.97 ±4.76^{bA}	469.22 ±10.17^{aA}	490.27 ±11.15^{aA}	**
6	292.57 ±4.48^{cB}	288.00 ±5.94^{cB}	323.47 ±11.43^{bB}	344.74 ±3.88^{aB}	**
12	244.63 ±4.88^{cC}	242.13 ±2.15^{cC}	284.62 ±3.35^{bC}	293.62 ±4.56^{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.
* Significant at $p < 0.05$.
** Significant at $p < 0.01$.
NS – not significant.

surface microorganisms at a dose of 3 kGy and the microbial population was below the detection limit (less than 1 log 10 cfu·g^{-1}) at 6 and 9 kGy. A review of the literature revealed that gamma irradiation could effectively reduce the initial microbial load in a variety of commercially valued products (Al-Bachir, 2015a; Al-Bachir, 2015b; Al-Bachir and Al-Adawi, 2015). A reduction in fungi has been achieved in peanuts by using a dose of irradiation ranging from 5 to 10 kGy (De Camargo et al., 2012; Chiou et al., 1990).

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 lack of exposure to light (Astoreca et al., 2007; Braghini et al., 2009). Differences in the resistance of microorganisms to gamma radiation is not restricted to genera, but is also observed between strains of the same species (Astoreca et al., 2009). Gamma rays cause different degrees of cell damage. Biological damage is mostly indirect, and mediated by reactive oxygen species (ROS), such as hydroxyl radical (HO$^{\bullet}$), superoxide radical (O_2), hydrogen peroxide (H_2O_2), single oxygen, etc., generated by the radiolysis of water (El-Beltagi et al., 2011). These reactive species are known to be highly reactive to membrane lipids, protein and DNA. They are believed to be the major contributory factors to stress injuries and to cause rapid cellular damage (Afify et al., 2011; Aly and El-Beltagi, 2010).

Table 3. Total bacterial [log 10 cfu·g] and fungal [log 10 spores/g] count of peanut seeds

Storage period months	Treatment				
	control	3 kGy	6 kGy	9 kGy	*p*-level
	Total bacterial count, log 10 cfu·g				
0	2.68 ±0.08^{aC}	<1^{b}	<1^{b}	<1^{b}	*
6	2.86 ±0.03^{cB}	2.19 ±0.02^{b}	<1^{a}	<1^{a}	*
12	3.18 ±0.02^{cA}	2.56 ±0.0^{2b}	<1^{a}	<1^{a}	*
p-level	*	*	–	–	
	Fungal count, log 10 spores/g				
0	3.19 ±0.09^{bB}	<1^{a}	<1^{a}	<1^{a}	*
6	3.45 ±0.05^{bA}	<1^{a}	<1^{a}	<1^{a}	*
12	3.63 ±0.17^{bA}	<1^{a}	<1^{a}	<1^{a}	*
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.
* Significant at $p < 0.01$.

Table 4. Effect of gamma irradiation on the taste, texture, color and flavor of peanut seeds

	Treatment				
	control	3 kGy	6 kGy	9 kGy	*p*-level
Taste	3.96 ±0.69^{a}	3.88 ±0.99^{a}	3.92 ±0.97^{a}	4.17 ±0.82^{a}	NS
Flavor	3.79 ±0.78^{a}	3.71 ±1.04^{a}	3.79 ±0.98^{a}	3.96 ±0.91^{a}	NS
Color	3.83 ±1.09^{a}	3.83 ±0.92^{a}	3.83 ±1.01^{a}	4.00 ±0.89^{a}	NS
Texture	3.88 ±0.95^{a}	3.75 ±1.11^{a}	3.79 ±1.02^{a}	3.92 ±0.83^{a}	NS

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

Effect of irradiation on sensory quality

Sensory analysis was carried out on the acceptability of the peanut seeds. The data on sensory evaluation (taste, flavor, color and texture) presented in Table 4 showed that peanut seed samples irradiated with 9 kGy received the highest score, but this was not significant ($p > 0.05$), for sensory evaluation with mean values of 4.17 (taste), 3.96 (flavor), 4.00 (color) and 3.92 (texture). The increase in color in irradiated samples (at 9 kGy) might be attributed to the Maillard browning reaction. Abu et al. (2006) suggested that the color darkening in cowpeas with irradiation may be attributed only in part to Maillard-type reaction products. Perhaps the formation of non-Maillard-type pigments was mostly responsible for the color changes observed.

In the case of treated oil seeds and nuts, the volatile profiles are highly complex and are composed of

compounds arising not only from lipid oxidation, but also from Maillard reactions, Strecker degradation, and caramelization of sugars (Lima et al., 2012).

Lipid oxidation is the major form of deterioration in foods, even when the lipid content is very low. Quality problems due to lipid oxidation are in fact aggravated in low-fat foods, where oxidation decomposition has a greater impact on off-flavors (Frankel, 2005).

CONCLUSION

The present study on the radiation treatment of peanut seeds demonstrated that a radiation dose up to 9 kGy was found to be sufficient to ensure the microbiological safety of peanut seeds. The growth potential of the bacteria and fungi studied was lost within 6 and 9 kGy. Thus, after one year of analysis, it can be concluded that irradiation protected again bacterial and fungal growth and retained the nutritional components of samples during long-term storage. The overall sensory rating for the attributes tested appears not to be affected by the amount of ionizing radiation.

ACKNOWLEDGEMENTS

The author wishes to express his deep appreciation to the Director General of the Atomic Energy Commission of Syria (AECS) and the staff of the division of food irradiation.

REFERENCES

Abd El-Aziz, A. B., Abde El-Kalek, H. H. (2011). Antimicrobial proteins and oil seeds from pumpkin (*Cucurbita moschata*). Nature Sci., 9(3), 105–119.

Abu, J. O., Muller, K., Duodu, K. G., Minnaar, A. (2006). Gamma irradiation of cowpea (*Vigna unguiculata* L.) flours and pastes: Effects on functional, thermal and molecular properties of isolated proteins. Food Chem., 95, 138–147.

Afify, A. M. R., El-Beltagi, H. S., Fayed, S. A., Shalaby, E. A. (2011). Acaricidal activity of successive extracts from *Syzygium cumin* L. Skells (Pomposia) against *Tetranychus urticae* Koch. Asian Pac. J. Trop. Biomed., 1(5), 359–364.

Ajayi, I. A., Oderinde, R. A., Kajogbola, D. O., Uponi, J. I. (2006). Oil content and fatty acid composition of some underutilized legumes from Nigeria. Food Chem., 99, 115–120.

Al-Bachir, M. (2004). Effect of gamma irradiation on fungal load, chemical and sensorycharacteristics of walnuts (*Juglans regia* L.). J. Stored Prod. Res., 40, 355–362.

Al-Bachir, M. (2015a). Microbiological, sensorial and chemical quality of gamma irradiated pistachio nut (*Pistachia vera* L.). Ann. Univ. Dunar. Jos Galati – Food Techn., 38(2), 57–68.

Al-Bachir, M. (2015b). Assessing the effects of gamma irradiation and storage time in quality properties of almond (*Prunus amygdalus* L.). Innov. Rom. Food Biotechn. 16, March, 1–8.

Al-Bachir, M., Al-Adawi, M. A. (2015). Comparative effect of irradiation and heating on the microbiological properties of licorice (*Glycyrrhiza glabra* L.) root powders. Int. J. Radiat. Biol., 91(1), 112–116.

Aly, A. A., El-Beltagi, H. E. S. (2010). Influence of ionizing irradiation on the antioxidant enzymes of *Vicia faba* L. Grasas Aceit., 61(3), 82–94.

AOAC (2010). Official methods of analysis. Washington, D.C.: Association of Official Analytical Chemists.

Aremu, M. O., Akinwumi, O. D. (2014). Extraction, compositional and physicochemical characteristics of cashew (*Anarcadium occidentale*) nut reject oil. Asian J. Appl. Sci. Eng., 3(7), 33–40.

Arici, M., Colark, F. A., Gecgel, U. (2007). Effect of gamma radiation on microbiological and oil properties of black cumio (*Nigella sativa* L.). Grasas Aceit., 58(3), 339–343.

Astoreca, A., Barberis, C., Magnoli, C., Combina, M., Dalcero, A. (2009). Ecophysiological factor effect on growth rate, lag phase and ochratoxin. A prodution by *Aspergillus niger* agregate strains on irradiated peanut seeds. Int. J. Food Microbiol., 129, 131–135.

Astoreca, A., Magnoli, C., Ramirez, M. L., Combina, M., Dalcero, A. (2007). Water activity and temperature effects on growth of *Aspergillus niger*, *A. awamori* and *A. carbonarius* isolated from different subtract in Argentina. Int. J. Food Microbiol., 119, 314–318.

Aziz, N. H., El-Far, F. M., Shahin, A. A. M., Roushy, S. M. (2007). Control of *Fusarium* moulds and fumonisin B1 in seeds by gamma-irradiation. Food Contr., 18, 1337–1342.

Braghini, R., Sucupira, M. M., Rocha, L. O., Reis, T. A., Aquino, S., Correa, B. (2009). Effects of gamma radiation on the growth of *Alternaria alternaria* and on the production of alternariol and alternariol monomethyl ether in sunflower seeds. Food Microbiol., 26(8), 927–931.

Chiou, R. Y. Y., Lin, C. M., Shyu, S. L. (1990). Property characterization of peanut kernels subjected to gamma irradiation and its effect on the outgrowth and aflatoxin production by *Aspergillus parasiticus*. J. Food Sci., 55, 210–213.

Davis, J. P., Dean, L. O., Faircloth, W. H., Sanders, T. H. (2008). Physical and chemical characterizations of normal and high-oleic oils from nine commercial cultivars of peanut. J. Am. Oil Chem. Soc., 75, 235–243.

De Camargo, A. C., Souza Vieira, T. M. F., Arce, M. A. B. R., Alencar, S. M., Domingues, M. A. C., Canniatti-Brazaca, S. G. (2012). Gamma radiation induced oxidation and tocopherols decrease in in-shell, peeled and blanched peanuts. Int. J. Mol. Sci., 13, 2827–2845.

Dorner, J. W. (2008). Management and prevention of mycotoxins in peanuts. Food Addit. Contam., A, 25, 203–208.

El-Beltagi, H. S., Ahmed, O. K., El-Desouky, W. (2011). Effect of low doses gamma irradiation on oxidative stress and secondary metabolites production of rosemary (*Rosmainus officinalis* L.) callus culture. Radiat. Phys. Chem., 80(9), 968–976.

Francisco, F. G., Usberti, R. (2008). Seed health of common bean stored at constant moisture and temperature. Sci. Agricol., 65, 613–619.

Fransisco, M. L. D. L., Resurrection, A. V. A. (2008). Functional components in peanuts. Crit. Rev. Food Sci. Nutr., 48, 715–746.

Frankel, E. N. (2005). Lipid oxidation. Bridgwater: The Oily Press.

Hania, F. G., El-Niely, G. (2013). The effect of irradiation treatment on the non-enzymatic browning reaction in legume seeds. Arab J. Nucl. Sci. Appl., 46(1), 313–327.

Jan, S., Parween, T., Siddiqi, T. O., Mahmooduzzafar, (2012). Effect of gamma radiation on morphological, biochemical, and physiological aspects of plants and plant products. Environ. Rev., 20, 17–39.

Jittrepotch, N., Kongbangkerd, T., Rojsuntornkitti, K. (2010). Influence of microwave irradiation on lipid oxidation and acceptance in peanut (*Arachis hypogaea* L.) seeds. Int. Food Res. J., 17, 173–179.

Lima, J. R., Garruti, D. S., Bruno, L. M. (2012). Physicochemical, microbiological and sensory characteristics of cashew nut butter made from different kernel grades-quality. LWT – Food Sci. Technol., 45, 180–185.

Mexis, S. F., Kontominas, M. G. (2009). Effect of gamma irradiation on the physic-chemical and sensory properties of raw shelled peanuts (*Arachis hypogaea* L.) and pistachio nuts (*Pistacia vera* L.). J. Sci. Food Agric., 89, 867–875.

Niyas, Z., Variyar, P. S., Gholap, A. S., Sharma, A. (2003). Effect of gamma irradiation on the lipid profile of nuymeg (*Myristica fragrans* Houtt). J. Agric. Food. Chem., 51(22), 6502–6504.

Paez, C. L. R., Reyes, M. C. P., Aguilar, C. H., Pacheco, F. A. D., Martinez, E. M., Orea, A. C., Bonilla, J. L. L. (2011). Control of natural mycobiota in maize grains by ultraviolet (UVC) irradiation. Acta Agrophys., 18(2), 375–388.

Sanchez-Bel, P., Egea, I., Romojaro, F., Martinez-Madrid, M. C. (2008). Sensorial and chemical quality of electrón beam irradiated almonds (*Prunas amygdalus*). LWT – Food Sci. Technol., 41, 442–449.

Seda, H. A., Moran, G. S., Mahmoud, A. A., Elneily, H. F. (2001). Chemical and biological changes of peanut kernels by gamma radiation. Ann. Agric. Sci., 46, 233–251.

Snedecor, G., Cochran, W. (1988). Statistical methods (pp. 221–221). Ames, Aiwa: The Iowa State Univ. Press.

Stevenson, D. G., Eller, F. J., Wang, L., Jane, J. L., Wang, T., Inglett, G. E. (2007). Oil and tocopherol content and composition of pumpkin seed oil in 12 cultivars. J. Agric. Food Chem., 55, 4005–4013.

Taha, F. S., Wagdy, S. M., Singer, F. A. (2012). Comparison between antioxidant activities of phenolic extracts from different parts of peanut. Life Sci. J., 9(2), 207–2015.

Wen, H. W., Chung, H. P., Chou, F. I., Lin, I., Hsieh, P. V. (2006). Effect of gamma irradiation on microbial decontamination, and chemical and sensory characteristics of lucium fruit. Radiat. Phys. Chem., 75, 596–603.

Yoshida, H., Hirooka, Y., Tomiyama, Y., Nagamizu, T., Mizushina, Y. (2005). Fatty acid distributions of triacyglycerols and phospholipids in peanut seeds (*Archis hypogaea* L.) following microwave treatment. J. Food Comp. Anal., 18, 3–14.