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ORIGINAL ARTICLE

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Compositions and microbial properties of gamma irradiated apricot (*Prunus armeniaca* L.) kernel

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Background: Gamma radiation is used to disinfestations and decontamination of dried food.

Methods: The current study evaluates the outcome of gamma irradiation doses (0, 6 and 9 kGy) on chemical compositions and microbial load of apricot kernel during storage at ambient temperature.

Results: Results indicated that apricot kernels were rich in oil (40.27%), protein (21.78%) and essential minerals (2.87% ash). Crude protein & fat and reduced sugars were not significantly affected by different gamma irradiation doses. In contrast, a statistically significant difference for moisture ash and total sugar was reported in comparison with the irradiated ones. Doses of the used gamma irradiation reduced the mean total viable count (TVC), mould and yeast count (MYC) and the total coliform counts (TC) in apricot kernel below the detection limit, and it remained undetectably low in irradiated samples during all months of storage.

Conclusion: Gamma irradiation treatment may be a useful way for maintaining apricot kernel quality and can be used as a preservation method.

Key words: Apricot kernel, Microbial, Irradiation, compositions

Apricot (*Prunus armeniaca* L. *Rosaceae*) is an attractive, delicious and highly nutritious fruit being cultivated in moderate climates of all the continents of the world, Asia and Europe being the largest producers (Bhat *et al*. 2013). Fruit contain different level of phytochemicals, which significantly contribute to nutritive value (Korekar *et al*., 2011). The kernels of most varieties of apricot are sweet, while the kernels of other varieties including wild apricot are bitter (Kaya *et al*. 2008). The seed percentage in the apricot fruit is about 15% and the kernel represents about 34% of the seeds (Mandal *et al*. 2007). Apricot kernels have very important roles in human nutrition as an important source of protein, oil and fibers (Kalia *et al*. 2017; Ozcan *et al*. 2010). Apricot kernel oil considered a good source of unsaturated fatty acids, and that oleic acid and linoleic acid correspond to approximately 92 g 100 g^{-1} of total fatty acids present (Cos *et al*. 2006). Several reports concerning the physic-chemical properties of apricot kernels are available in the literature (Yigit *et al*. 2009). Sweet apricot kernels taste like almond kernel and thus used as food ingredient in a dried form (Korekar *et al*. 2011). Apricot kernel oil has been used in cosmetics and as pharmaceutical agents that are economically important products for many regions (Karsavuran *et al*. 2015).

Irradiation is one of the most widely investigated ways of food preservation methods and has been shown to be effective, economic and safe through extensive research (Shahbaz *et al*. 2016). The technology of food irradiation is an established method employed to improve the microbial and fungal properties of different type of foods has been investigated and is currently applied at a commercial scale in different countries worldwide (Al-Bachir 2014; 2016a; 2016b; Bhatti *et al*. 2013). Improvement of this preservation method is carried out taking into consideration that high energy irradiation might affect the nutritive value of irradiated food (Al-Bachir 2015). However, the effect of radiation on the characterization of foods must be analyzed in order to comprehensively assess the acceptability of irradiated foods (Azim *et al*. 2009). Moreover, detailed literature on proximate composition of apricot kernel is scare. To our knowledge, until now there are little information in the literature on irradiated apricot kernels. Therefore, the present investigation is carried out to study the compositions and microbial load of irradiated and control samples of apricot kernels.

MATERIALS AND METHODS

Plant materials and preparation

Apricot seeds (stone/pit) were collected from different locations at Damascus, Syria. Individual stones were hammered to obtain the seed kernels. The skin was removed and the kernel was left to air-dry for two days at room temperature. Kernels were cleaned, dried, and were broken into paces smaller than 1 mm using a domestic grinder before they were sieved. Apricot kernels were kept in polyethylene pouches until irradiation. Each pouch of apricot kernels (250 g) was considered as a replicate.

Treatments and analysis performed

Apricot kernels were irradiated with several doses of 0, 6 and 9 kGy, at room temperature, using a gamma source 60CO (ROBO, Russa) with a dose rate of 7.775 kGy h-1. The absorbed dose was monitored by alcoholic chlorobenzene dosimeter (Al-Bachir 2014). The irradiated and control samples of kernels were stored for 12 months at ambient temperature (18-25 oC) under relative humidity (RH) of 50-70%. Microbial load, physical and chemical analyses were performed on both samples (irradiated and controls) immediately after irradiation, and after 12 months of storage.

Chemical analysis

The recommended methods of the Association Official Analytical Chemists (AOAC) were used to determine the chemical composition of apricot kernel including the contents of moisture in an oven at 105 ± 1 ^{o}C to a constant weight, ash by incinerating the sample at 550 ^{o}C, crude protein by micro-Kjeldahl apparatus, and oil in a Soxhlet apparatus using hexan as a solvent.

The total sugar were estimated according to the standard method by using Anthrone indicator and measuring the measuring the absorbance at 620 nm with a T70 UV/VIS spectrophotometer, (PG Instrument Ltd). The reducing sugar of apricot kernel were

determined according to the AOAC standard method 923.09 using Fehling methods (AOAC 2010). Mineral (K) ,Ca, Mn, Fe, Ni, Cu, Zn, Br, Rb, Sr and Pb) were estimated using XRF instrument, which was equipped with a 2 kW Mo tube and a Si(Li) semiconductor detector with an energy resolution of 160 eV at 5.9 keV. The operating conditions were the same as described in the earlier work (Khuder *et al*. 2012).

Microbiological analysis

Standard plate count method was employed to enumerate the total microbial load in terms of colony forming units in the control and irradiated samples (AOAC 2010).

Total bacterial counts were determined using the plate count technique on agar plate counts (APCs) (Oxoid, CM 325, UK) at 30 oC for 48 hours. Fungus count was determined using the plate count technique on Dichloran Rose-Bengal Chloramphenicol Agar (DRBC) (Merck, 1.00466, Germany) at 25 oC for 5 days. The colony forming units (CFUs) were expressed by means of CFU log.

Statistical analysis

All procedures were carried out in triplicate and the data were statistically analyzed using the analysis of variance test (ANOVA) and the SUPERANOVA computer package (Abacus Concepts Inc, Berkeley, CA, USA; 1998). Duncan's multiple range test was used to separate the means and significances were accepted at 5% confidence level ($p < 0.05$).

RESULTS AND DISCUSSION

Apricot kernel composition

The quality or nutritive value of any plant food for human nutrition, including seeds, depends on its basic constituents, including proteins, carbohydrates, fat and minerals (Maity *et al*. 2009). The analytical values of protein, oil, ash, fiber and mineral contents may be useful for dietary information, which requires prior knowledge on the nutritional composition of apricot kernels (Haciseferogullari *et al*. 2011).

The proximate composition of irradiated and nonirradiated apricot kernels is given in Table 1. The moisture percentage of apricot kernels was found to be 2.74% with the total crude protein, total crude fat, ash, total sugar and reducing sugar of 21.78, 40.27, 2.87, 11.98, and 2.26%, respectively. The high protein content is indicative that the apricot kernel is very suitable for human nutrition or to improve nutritional values of meal. However, due to a high oil percentage, these products could be used as a potential source of oils. Our results are similar in composition of apricot kernel when compared to the values known in the literature. In confirmation to these results, the moisture, crude protein, crude lipids, total sugar and total ash in apricot kernels were recorded as 4.0-4.1%, 20.2-31.7%, 31.6-46.3%, 6.3-9.3% and 1.7-2.7%, respectively (Gupta *et al*. 2012; Tusimova *et al*. 2017; Ozcan *et al*. 2010). As shown in many studies, protein, oil, sugar, and ash were affected by climate, variety, geographical origin, harvest year and the methods of cultivation (Haciseferogullari *et al*. 2007).

The dried apricot kernels contained very low moisture (2.74 %), and they were safe for long period storage without spoilage, because, generally, dried apricot kernels having this low moisture content are not highly susceptible to microorganisms (Gohari Ardabili *et al*. 2011). The value of the moisture percentage falls within the range of values of moisture percentage for kernels and legumes which range between 7.85 and 11.0% (Aremu and Akinwumi 2014).

Ash content determination is important because it is an index of the quality of nutrition materials. A value of 2.87% obtained for ash content of apricot kernel is high. Aremu and Akinwumi (2014) recommended that ash content of nuts and seeds should fall in the range 1.5 – 2.5% in order to be suitable for human consumption or animal feeds.

The mineral contents of apricot kernels were determined by XRF as: (K (9689 ppm), Ca (2028), Mn (25.9), Fe (82.5), Ni (<1.92), Cu (9.78), Zn (60.8), Br (0.67), Rb (8.72), Sr (1.92) and Pb (1.90)). Potassium was the most abundant mineral in apricot kernel. Apricot kernels are also a good source of minerals, particularly K, Ca Mn and Fe. The high percentage of potassium, and calcium, together with the content of the essential elements as iron manganese copper and zince allow the apricot kernels to be considered as an excellent source of macro- and micro- bio-elements (Heghedus-Mindru *et*

al. 2014). Analysis of samples for hazardous elements show that concentration of Pb in studied apricot kernel samples were 1.9 ppm for dried samples, which was lower than limited concentration (5.5 ppm) of this heavy metal in dried food samples (Davarynejad *et al*. 2010). According to Ozcan *et al*. (2010), average mineral percentages of apricot varieties were found to be between 6206-12715 ppm for K, 1063-2220 ppm for Ca, 1.5- 45.77 ppm for Cu. These differences in minerals may be due to varieties, genetic factors, growth locations, geographical variations, soil properties, harvesting time, and analytical procedures (Ozcan *et al*. 2008).

Effect of gamma irradiation and storage on composition of apricot kernel

Table 1 shows the moisture, crude protein, crude fat, ash, total sugar and reducing sugars for the non-irradiated and irradiated apricot kernels with 6 and 9 kGy. Analysis of variance showed that parameters such as crude protein crude fat, and reducing sugar were not significantly affected by different gamma irradiation doses. Our results are in agreement with previous reports which also reveal no significant difference on chemical characteristics including fat, ash and protein contents between irradiated and non-irradiated almond and canola seeds (Bhatti *et al*. 2013; Ebrahimi *et al*. 2009). On the other hand, a small but statistically significant ($p<0.05$) different was reported in comparison with the irradiated ones for moisture, ash and total sugar. The results showed that the moisture percentage of irradiated samples of apricot kernel was increased. This could be due to the difference in the extent of water hydrolysis by gamma irradiation (Kortei *et al*. 2017). While, the total sugar percentage of irradiated samples were decreased. Also, the increase in water content and the decrease in sugar content in irradiated apricot kernel could be attributed to the stimulatory effect of irradiation on some metabolic processes involving the conversion of sugar into water (Al-Bachir 1999). These results are in agreement with Ramadan *et al*. (2017). They reported that the percentage of all sugars immediately decreased after irradiation at dose of 4 kGy. Thus, given that the moisture percentage of the samples in this study was very low (2.74%). It was to be expected that both the protein and fat percentage would remain largely unaltered throughout the assay, for all the treatments applied.

Regarding the total sugar content, there was a small but significant ($p<0.05$) reduce following the irradiation treatments, for the tow doses used. The values being 11.65% for samples irradiated at 6 kGy, and 11.04% for these receiving 9 kGy, compared with 11.98% for control samples (Table 1). These results demonstrated the limited effect of the gamma irradiation process on the sugar levels in the apricot kernels. This could be explained by the low moisture percentage of this type of product, since it has been shown that the levels of radiolytic materials producing from the sugars exist in irradiated food products are much lower when the moisture percentage is low (Sanchez-Bel, *et al*. 2008). The irradiation treatments of carbohydrates catalyze the break of the other bonds between hexose residues in high-molecular weight carbohydrates, as well as the dehydration of monosaccharide, so that the content of monosaccharide should increase as a result of this process (Siddhuraju *et al*. 2002). The radiolytic compounds that can form, after an irradiation treatment, from the compounds already present in the food stuff depend directly on the water content; because of this when kernels, seeds or dried products are irradiated, the expected modifications are much less. But, the damage inflicted by irradiation on the peptide bond depends, and to the degree of hydration of the products, greatly on the oxygen content, since this bond is highly stable and is not normally broken by the irradiation doses generally applied to food stuff (Sanchez-Bel, *et al*. 2008).

In the present study, the moisture, crude protein, crude fat, ash, and total sugar contents of the apricot kernel samples were practically constant for control sample, and during the whole storage period. While, the moisture, crude protein and ash, contents of the apricot kernel samples were practically constant for all the irradiation doses applied, and during the whole storage period, supporting the idea that treatment with gamma irradiation does not influence these parameters at the doses applied, and suggesting that the storage conditions assayed in our study were appropriate for this plant materials.

Table 1. Concentration of elements analyzed by XRF of apricot seed.

Elements	Concentration (ppm)
K	9689±1119
Ca	2028±236
Mn	25.9±4.0
Fe	82.5±9.6
Ni	<1.92
Cu	9.78±2.7
Zn	60.8±7.4
Br	0.670±0.185
Rb	8.72±1.05
Sr	1.92±0.27
Pb	1.90±0.11

Table 2. Effect of gamma irradiation and storage period on moisture, ash, protein, total sugar, reducing sugar and fat contents (%) of apricot seed.

Treatment	Control	6 KGY	9 KGY	P level
Storage period/ (Months)		**Moisture (%)**		
0	$2.74\pm^{Ba}0.15$	$3.16\pm^{Aa}0.44$	$2.91\pm^{Ba}0.26$	**0.313**
12	$3.93\pm^{Aa}0.20$	$3.83\pm^{Aa}0.23$	$3.72\pm^{Aa}0.05$	**0.413**
P level	**0.001**	**0.082**	**0.006**	
		Crude protein (%)		
0	$21.78\pm^{Aa}0.30$	$22.24\pm^{Aa}0.45$	$21.87\pm^{Aa}0.06$	**0.251**
12	$22.07\pm^{Aa}0.29$	$21.74\pm^{Ba}0.42$	$21.56\pm^{Aa}0.41$	**0.315**
P level	**0.304**	**0.235**	**0.259**	
		Crude fat (%)		
0	$40.27\pm^{Aa}1.123$	$36.94\pm^{Ab}1.79$	$40.23\pm^{Aa}0.93$	**0.035**
12	$38.68\pm^{Aa}3.22$	$38.43\pm^{Aa}2.88$	$41.01\pm^{Aa}2.39$	**0.513**
P level	**0.465**	**0.488**	**0.0001**	
		Ash (%)		
0	$2.87\pm^{Ba}0.08$	$3.01\pm^{Aa}0.56$	$3.20\pm^{Aa}0.18$	**0.530**
12	$3.11\pm^{Aa}0.05$	$3.09\pm^{Aa}0.02$	$3.11\pm^{Aa}0.03$	**0.721**
P level	**0.013**	**0.824**	**0.425**	
		Total sugar (%)		
0	$11.98\pm^{Aa}0.05$	$11.65\pm^{Bb}0.03$	$11.04\pm^{Bc}0.19$	**0.0001**
12	$12.21\pm^{Aa}0.15$	$12.19\pm^{Aa}0.08$	$11.84\pm^{Aa}0.28$	**0.088**
P level	**0.076**	**0.0003**	**0.014**	
		Reducing sugar (%)		
0	$2.26\pm^{Ab}0.06$	$2.37\pm^{Aa}0.02$	$2.24\pm^{Ab}0.03$	**0.016**
12	$2.19\pm^{Aa}0.08$	$2.13\pm^{Ba}0.06$	$2.08\pm^{Ba}0.03$	**0.193**
P level	**0.288**	**0.003**	**0.002**	

^{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

Table 3: Total bacterial (log10 cfu g) and fungal (log10 spores /g) count of apricot seed.

Treatment	Control	6 KGY	9 KGY	P level
Storage period/ (Months)		**Total bacterial count (log10 cfu g)**		
0	$3.79\pm^{Aa}0.20$	ND^{b}	ND^{b}	**0.0001**
12	$4.08\pm^{Aa}0.27$	ND^{b}	ND^{b}	**0.0001**
P-level	**0.205**			
		Fungal count (log10 spores g)		
0	$3.27\pm^{Aa}0.05$	ND^{b}	ND^{b}	**0.0001**
12	$3.67\pm^{Ba}0.15$	ND^{b}	ND^{b}	**0.0001**
P-level	**0.576**			
		Total coliform(log10 cfu g)		
0	$2.59\pm^{Aa}0.17$	ND^{b}	ND^{b}	**0.0001**
12	$2.70\pm^{Aa}0.25$	ND^{b}	ND^{b}	**0.0001**
P-level	**0.012**			

^{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
$^{ND:}$ not detected.

Microbial load of apricot kernel

The extents of contamination by microorganisms in apricot kernels, as affected by gamma irradiation were determined. As shown in the results on microbiological quality of apricot kernels (Table 1). The mean total viable count (TVC), mold, yeast count (MYC) and total coliform counts (TC) for the apricot kernels are 3.79, 3.27 and 2.59 log10 cfu respectively. A total viable count is indicative of the populations of contaminated microorganisms and act as an index of hygienic quality (Adu-Gyamfi and Appiah 2012). The microbial load of un-irradiated samples of apricot kernel was low indicating high product quality, possibly due to their dried nature and consequently low moisture. In preserving foods by drying, one seeks to lower the moisture percentage to point where the activities of food spoilage and food-poisoning microorganisms are inhibited. Bacteria require relatively high levels of moisture for high growth, with yeast requiring less and mold still less. The low moisture percentage along with high sugar contents has made an increase the resistance of microbial deterioration where these conditions are unfavorable for the growth of microorganisms (Ramadan *et al*. 2017). High total coliform counts are usually associated with significant levels of enteric pathogens (Adu-Gyamfi and Appiah 2012).

Effect of gamma irradiation on microbial load of apricot kernel

Irradiation technology is one of methods used to prevent contamination in many foods. It has been suggested as the non-thermal methods for destroying pathogenic and spoilage microorganisms in the final products (Al-Bachir 2014, 2015; 2016a; 2016b). Irradiating the apricot kernel decreased the microbial count significantly. Doses of 6 and 9 kGy completely eliminated all microorganisms count (TVC, MYC and TC) from the apricot kernel. This is to be expected since irradiation is one of the few processes that the microbiological quality of food can be substantially improved by irradiation and guarantees high hygienic quality (Adu-Gyamfi and Appiah 2012). Also, molds are known to be sensitive to irradiation (Arici *et al*. 2007); hence, a dose of 6 kGy completely eliminated the fungal population. The results seem to suggest that improving the quality and degree of drying the apricot kernel could

possibly reduce the effective decontamination doses from 9 to 6 kGy. Some previous study showed that gamma irradiation at dose of 5 kGy was sufficient to eliminate or reduce up to acceptable level the microbiological contamination of dried food ingredients (Janika *et al*. 2017). So we can say that 6 kGy irradiation dose is used for decontamination of dry food products which specifies that dose as the effective and recommended dose for application (Adu-Gyamfi and Appiah 2012; Al-Bachir 2014; Al-Bachir 2015; Al-Bachir 2016a; Al-Bachir 2016b;). Elimination of aerobic microorganism could take a high dose of irradiation because of it formation of free radical in the cell (Moniruzzaman *et al*. 2016). Radiation produces various types of DNA damage. DNA damage is the first event immediately after exposure to ionizing radiation followed by cell membrane damage (Maity *et al*. 2009). Gamma irradiation inactivate microbes by destroying nucleic acids directly as consequence of electron and photon content with DNA and RNA as well as indirectly through the enhanced generation of reactive oxygen species (ROS), therefore, obstructing bacteria division (Jayathilakan *et al*. 2017).

CONCLUSION

Our results indicated that apricot kernels, which are by product of apricot fruit, is highly rich raw material in oil and protein. Furthermore, apricot kernel is a relatively good source of essential minerals. Gamma irradiation was effective in reducing microorganisms load of apricot kernel. Nevertheless, irradiation had no effects on the chemical characteristics of apricot kernels. Based on these findings, it could be suggested that gamma rays treatment may be a useful non-chemical way for maintaining apricot kernel quality and can be used as a preservation method for this type of materials.

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CONFLICTS OF INTEREST

Authors declared no potential conflict of interest

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