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Impact of Gamma Irradiation on Fatty Acid Profile of Different Types of Pistachios in Kerman Province

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ABSTRACT

One way to protect food and nutrients is to use gamma irradiation. Gamma rays are capable of influencing fatty acids, thus, this research was carried out to test the impact of using gamma rays on pistachio stored for six months and to determine the optimal effective dose of gamma with no negative impact on the amount of fatty acids in different types of pistachios. Three doses including 3, 5, and 9 kGy of gamma rays were used to protect and store different pistachios in Kerman. After being exposed to gamma rays, the pistachios were stored for six months in a storehouse at 5°C and (9-43%) RH. Every three months, the samples were analyzed. The greatest amount of oleic acid was found in Ahmad Aghaei pistachio type (62.08%) followed by Ohadi (61.03%), Kaleh Qouchi (59.83%), and Akbari (55.80%) types (P< 0.05). Over time, oleic acid and unsaturated fatty acids decreased in all of the control and test samples. After three months of storing, in Ahmad Aghaei pistachios irradiated with a 3 kGy dose of gamma, the amount of oleic acid fatty acid was 45.15%. With 5 kGy dose, after three months, oleic acid fatty acid was 66.65%, and with 9 kGy dose after three months, it was 59.90%. Therefore, it can be concluded that the use of irradiation doses of 5 and 9 kGy affects the increase of unsaturated and derived fatty acids, thus, the dose of 5 kGy irradiation is most appropriate.

Keywords: Ahmad Aghaei pistachio, Fatty Acid Profile, Gamma Irradiation, Oleic acid, Storage.

INTRODUCTION

Irradiation is useful to increase the life span of food and food quality security. It decreases microbial load. This is a method for keeping different cereals, spices, dried fruits, and grains (Al-Bachir, 2004). The importance of irradiation is not only for the decrease of unwanted microorganisms and increase of protection duration, but it also affects the physicochemical, nutritional, and biological properties of foods (Afify *et al.*, 2013). An unwanted impact of irradiation is the formation of oxidized lipids by the reaction of membrane lipid and other food fats with oxygen radicals produced by gamma rays (Nam and Ahn, 2003). This can negatively affect human health. This method focuses on a lower dose of irradiation with less ensuing damages to nutrients, which bears positive influences as well. Sometimes, high doses of irradiation cause unwanted changes in the taste and appearance of foods, rendering the products unhealthy for human consumption (Sanchez-Bel *et al.*, 2005).

Saturated and unsaturated fatty acids have different impacts on human health. Medium-chain fatty acids do not increase ceramides or

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intermediates for the synthesis of triglycerides in the cells. However, like long-chain fatty acids, they are influential in establishing insulin resistance (Hoeks *et al*., 2012). On the contrary, it has been found that oleate, as an unsaturated fatty acid, resist Palmitate impact in muscle cells that cause inflammation and insulin resistance. Oleate cause the accumulation of triglyceride and the increase of beta oxidation of fatty acids. It prevents the synthesis of diacylglycerol. This prevention retards the activation of Protein Kinase C-Theta (PKCθ) and Nuclear Factor Kappa-light-chain-enhancer of activated B cells (NF-κB) that have essential role in disadjusting insulin signaling (Coll *et al*., 2008).

Compared to saturated fatty acids in butter, fish oil and olive oil, which are rich in, respectively, omega-3 fatty acids and oleate, fasting insulin level and Homeostasis Model Assessment of Insulin Resistance (HOMA- IR) has decreased, as a matter of fact, unsaturated fatty acids and omega-3 fatty acids play a less major role in establishing insulin resistance (Saidpour *et al*., 2011). Several studies show that the consumption of fatty acids with one or several unsaturated bonds increase sensitivity to insulin and improve a fatty liver (Masi *et al*., 2012).

Given the probable role of rays, the change in fatty acids' structure and the type of fatty acids impact on human health, this study examines the role of different doses of gamma irradiation on fatty acid profiles of pistachio. This research aimed to identify the most effective dose of gamma, which causes the least damage to the quality of pistachio fatty acids. Furthermore, due to the time span between irradiation and pistachio consumption by people, the quality of the fatty acids irradiated by 3, 5, and 9 kGy (kilo Gray) doses of gamma were to be analyzed after 3 and 6 months of being kept in a warehouse at 5°C and 9-43% RH.

MATERIALS AND METHODS

Provision of Pistachio Samples

In this study, pistachio samples of different types including Ohadi, Kaleh Qouchi, Akbari, and Ahmad Aghaei were obtained from Iranian Pistachio Research Centre located in Kerman Province. Then, the samples were analyzed in lab, and the defective or stained pistachios were separated. The goal of this phase was to ensure the health of the pistachios before irradiation, so that any stain or change of color could be identified. Then, the pistachios were packed in 500-grams polyethylene-polyester laminated plastic with thickness of 90 micron and size of 50×70 cm. It was flexible as well.

Pistachio Irradiation

To irradiate the samples, they were packaged inside corrugated cardboards with a thickness of 1 mm and a capacity of 10 kg. After the packages were marked, they were transferred to Atomic Energy Institution. The irradiation was done by Nordion gamma cell 220. Irradiation was done by power source of 423,500 curies; the lowest dose rate of the gamma dose was 0.03 Gy s^{-1} and the highest dose rate was 16.2 Gy s^{-1}. The irradiation time was 22 minutes for 3 kGy, 37 minutes for 5 kGy and 66 minutes for 9 kGy. Irradiation was done at a specified dose and time. The samples were stored for six months in a pistachio warehouse at 5 °C and 9-43% RH. After each three months, the test of fatty acid was carried out in the samples. The gamma ray penetration is very high. Because of this, the amount of gamma ray in all parts of the sample is the same. Under these conditions, a small amount of radiation energy was used to increase the thermal energy of the foodstuff.

Analyzing Fatty Acids

First, the pistachios were peeled and ground. Then, Hexane and isopropanol solvents, both of which included an industrial antioxidant known as Butylated HydroxyToluene (BHT) (0.01%), were used. First, 8 mL of isopropanol solution was added to the pistachio nuts and exposed to 80°C temperature for five minutes. Then, the temperature was cooled and 12 mL of Hexane was added and was homogenized for 30 minutes in a shaker incubator. The existing suspension was centrifuged and the front solvent including lipids was separated. The extraction of lipids was applied two more times to the sediment from the previous step by hexane-isopropanol (Volume ratio of 7: 2). The solvent was evaporated by a rotary evaporator and the remained lipids were used for the analysis.

To hydrolyze the lipids and release the fatty acids, soaping method was used. For this purpose, 10 mL of the extracted lipids were put in a test tube, to which 2 mL of molar potash produced in 95% ethanol was added, and it was put at room temperature for 24 hours. Then, 5 mL of distilled water was added to the solution and stirred by a vortex. Five mL of hexane-diethyl ether (volume ratio of one to one) was added to the solution and mixed by the vortex for 1 minute, and then separated by centrifuge.

Three mL of 6M HCl was added to the aqueous phase. Then 5 mL of hexane-diethyl ether (1:1) was added and the mixture was stirred by vortex. At this stage, the fatty acids entered the aqueous phase. Hexane was separated by centrifuge and washed three times by distilled water. It was dried by sodium sulfate. The hexane was evaporated in oven (40^{o}C), and the fatty acids were used to make methyl ester.

By using Boron triFluoride (BF3) solution in methanol, methyl ester of fatty acids was made. Hence, 1 mL of the BF3 solution was added to 14% methanol extracted in the previous stage, and the solution was strongly stirred in a closed tube. Then, it was put at 60^{o}C for 90 minutes, and every 20 minutes, the solution was stirred once. After 90 minutes, saturated solution of sodium bicarbonate and 2 mL of thermal hexane were added to it and mixed by vortex for 2 minutes. Then, 2 mL of thermal hexane was added again. The solution was once more stirred by vortex for 2 minutes and also centrifuged (4,000 rpm) at 4^{o}C. The supernatant included methyl ester of fatty acids. Later, 0.5 mL of hexane was injected in evaporation oven and GC device (Kangani *et al*, 2008).

The input temperature of the device was adjusted as 300^{o}C; carrier gas pressure as 30 psi, and system split 30:1. The carrier gas included nitrogen with pressure gradient of 30 psi for 8 minutes. The pressure increase speed was set as 20-90 psi min^{-1}, which was maintained until the end. The oven temperature was set as 45^{o}C for 1 minute and the temperature was increased to 160^{o}C at the rate of 25^{o}C min^{-1} and to 195^{o}C at the rate of 30^{o}C min^{-1}. This temperature was kept until the end of separation phase. FID detector temperature was 350^{o}C, and the flow of hydrogen gas and air were, respectively, 30 and 300 mL min^{-1}.

Statistical Analysis

The mean of the data was obtained from three iterations. To estimate the mean of the groups with three different doses of gamma, one way ANOVA was utilized. The data analysis was done by SPSS software (version 20). Duncan test was used to determine the significance level in different groups ($P< 0.05$). All measurements were performed in three replications. In grouping, the greater parameter is shown with letter "*a*". The meas are given by Standard Deviation (SD).

RESULTS AND DISCUSSION

Table 1 shows the fatty acid compounds of the control (non-irradiated) pistachios. The most important fatty acids in different pistachio types included saturated fatty myristic acid (C14:0) and palmitic acid (C16:0), which varied between, respectively, 0.2-0.86% and 11.08-8%. Oleic acid

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Table 1. The fatty acids contents extracted from different types of pistachio (with no irradiation) after 3 and 6 months of storage.[a]

Cultivar	Ohadi		Akbari		Kaleh Qouchi		Ahmad Aghaei	
	Storage time							
Fatty acid	3 months	6 months	3 months	6 months	3 months	6 months	3 months	6 months
Myristic acid%	0.09±0.00d	0.20±0.05c	0.83±0.00b	0.86±0.00a	0.10±0.00d	0.12±0.00d	0.09±0.00d	0.13±0.03d
Palmitic acid%	0.00 ±9.44f	10.02±0.00d	9.93±0.00e	10.2±0.05c	0.00±46/10b	0.00 ±11.08a	8±0.00h	0.00 ±9.07g
Oleic acid%	61.03±0.00c	60.23±0.00d	55.8±0.03g	03.0 ± 53.0h	59.83±0.000e	56.02±0.00f	63.22±0.00a	62.08±0.00b
Linoleic acid%	27.78±0.00b	26.02±0.00d	27.81±0.00b	26.08±0.00d	26.76±0.00c	25.87±0.00d	26.13±0.00d	37.92±0.00a
Gamma linolenic acid%	0a	0a	0a	0a	0a	0a	0a	0a
Alpha linolenic acid%	0.4±0.00f	0.4±0.00f	0.51±0.00c	0.45±0.00e	0.61±0.00a	0.51±0.00c	0.54±0.00b	0.48±0.00d
Eicosanoic acid%	0.38±0.00a	0.2±0.00e	0.39±0.00a	0.32±0.00c	0.36±0.00b	0.32±0.00c	0.31±0.00c	0.26±0.00d
Stearic acid%	0a	0a	0a	0a	0a	0a	0a	0a
Palmitoleic acid%	0a	0a	0a	0a	0a	0a	0a	0a

[a] Numbers within each row followed by different small letters are significantly different ($P< 0.05$).

(C18:1), linoleic acid (C18:2), alpha-linolenic acid and eicosanoic acid were respectively found as 63.22-53.01, 37.92-25.87, 0.61-0.4, and 0.38-0.2%. The amount of saturated fatty acids increased in the storing phase, and, on the other hand, the unsaturated fatty acids decreased. These findings are in agreement with the findings of other researcher such as Al-Bachir (2014). The type of fatty acids and their amount in different types of pistachios were different under different environments and ecological conditions. In 2006, Seferoglu *et al.* (2006) demonstrated the impact of environment and ecology on the changes of fatty acids, which has been recently confirmed by Arena *et al.* (2007). In 2011, Gecgel *et al*. (2011) studied Anacitlak pistachio and found that in comparison with hazelnut, almond, and walnut, these pistachios did not have pentadecanoic acid, but included palmitic, stearic, oleic, and linoleic acid. However, there were other fatty acids such as Eicosanoic acid and Palmitoleic acid in small quantities. Abdolshahi *et al.* (2011) found that the fatty acid compounds of Akbari, Kaleh Qouchi, Khenjeri, Abbas Ali, and Shahpasande Damghan included 0.0-0.08% of myristic acid (C14:0), 11.1-10.2% of palmitic acid (C16:0), 55.2-48.9% of oleic acid (C18:1), 36.9-30.5% of linoleic acid (C18:2), and 0.8-0.35% of linolenic acid (C18:3). There is significant difference among different types of pistachios with respect to these fatty acids. Mohammad *et al.* (2007) carried out a research on the fatty acids of seven Iranian pistachios and found that the amount of palmitic acid (C16:0) in Ohadi pistachio was 7.2%, in Akbari pistachio 7.1%, in Fandoghi pistachio 8.6%, in Ahmad Aghaei pistachio 8.2%, in Qouchi 7.8%, in small Fandoghi 8.3% and in Zarand Badami 7.1% . Okay showed that the amount of unsaturated fatty acids differ in various types of pistachios and oleic acid is the most important unsaturated fatty acid (Okay, 2002). The second unsaturated fatty acid with high percentage is linoleic fatty acid. It is the most abundant in Kaleh Qouchi (36.8%) (Okay, 2002). In 2010, Tsantili *et al.* (2010)

delivered a research on several types of local pistachios and confirmed the existence of myristic acid, palmitic acid, palmitoleic acid, margaric acid, stearic acid, oleic acid, vaccenic acid, linoleic acid, linolenic acid, arachidic acid, gondoic acid and behenic acid. Oleic and linoleic acid as monounsaturated fatty acids, linoleic acid as a polyunsaturated fatty acid, and palmitic acid, as unsaturated fatty acid were the most abundant acids. Agar *et al.* (1998) found the inverse relationship of oleic and linoleic acid in pistachio. Kucukoner and Yurt (2003) discovered the inverse relationship between monounsaturated fatty acids and saturated fatty acids. In 2014, Al-Bachir (2014) focused on Halabi pistachio bought from Syrian local supermarkets, and he found that palmitic acid, palmitoleic acid, stearic acid, oleic acid, linoleic and linolenic acid were observed in the pistachios fatty acid profile. The most abundant acids were unsaturated fatty acids such as oleic and linoleic acid. After a year, some changes were observed during storage in warehouses. The amount of palmitic acid decreased and palmitoleic acid increased. There was also a decrease in stearic acid, linolenic and oleic acid, and an increase in linoleic acid.

Other findings of this research show the existence of more oleic and linoleic acid in comparison with other fatty acids. The greatest amount of unsaturated fatty acids in each of the two periods belonged to Ahmad Aghaei, which decreased as time elapsed. This decrease could be due to the storage duration and oxidation of the unsaturated lipid (Maskan and Karatas, 1999). After storage, oleic fatty acid decreased in all of the pistachio samples, except in the Akbari pistachios, which could be attributed to its strong physical structure and resistance against oxidation. There were significant differences between linoleic acid in the four pistachio types. There was a decrease in this acid after the storage time, except Ahmad Aghaei variety, and this decrease was significant. There was no gamma-linoleic acid in the four pistachio types. The most frequent unsaturated fatty acid was alpha-linoleic acid, which was respectively observed in Kaleh Qouchi and Ahmad Aghaei stored for three months, and decreased as time elapsed. In all of the pistachio types, palmitic acid increased after six months; the highest increase belonged to Ahmad Aghaei pistachio. Myristic fatty acid was almost the same in all of the pistachio samples. Stearic fatty acid and palmitoleic acid were reported as non-existent in all of the control samples. The decrease of unsaturated oleic acid led to the creation of alpha-linoleic and eicosanoic acid, which plays a role in many biological reactions of human body and is a fundamental plant acid (The British Nutrition Foundation, 2013). Golge and Ova (2008) found that, over time, significant changes occurred in the amount of palmitic, stearic, oleic and linoleic acid.

Table 2 shows the compounds of fatty acids in the irradiated pistachios with 3 kGy dose of gamma, stored for six months (two three-month periods) in a pistachio warehouse. Although oleic acid in Kaleh Qouchi and Ahmad Aghaei decreased compared to the control samples, there was significant increase during the six months of storage. The decrease of this fatty acid could be because of the change of oleic acid to gamma linolenic acid and alpha-linoleic acid. A little palmitoleic acid was also created in the Kaleh Qouchi and Ahmad Aghaei pistachios during the six months. The existence of these fatty acids is important for body health. Gamma-linoleic acid prevents the growth and spread of cancer cells. It also plays a role in absorption of calcium in people suffering from osteoporosis (Saidpour *et al*., 2011). There is no significant change in linoleic acid. Among the saturated fatty acids, palmitic acid decreased by the irradiation. This decrease was also in treatments after the six months, which led to the increase of derived fatty acids.

Table 3 shows the fatty acid compounds in the pistachios irradiated with 5 kGy dose of gamma in six months of storage. Oleic fatty acid increased by using a high dose gamma, but it decreased over time. The increase of the oleic acid led to the decrease of gamma-linoleic and alpha-linoleic acid. Palmitic acid increased in all of the pistachio types,

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Table 2. The contents of the fatty acids extracted from different types of pistachio irradiated with gamma (Dose= 3 kGy), after 3 and 6 months of storage.[a]

Cultivar	Ohadi		Akbari		Kaleh Qouchi		Ahmad Aghaei	
	Storage time							
Fatty acid	3months	6months	3months	6months	3months	6months	3months	6months
Myristic acid%	0.077±0.00058b	0.00058 ±0.08ab	0.082±0.00058ab	0.085±0.00058a	0.070±0.00058c	0d	0.068±0.00058c	0.082±0.00058ab
Palmitic acid%	8.92±0.0003b	7.33±0.0003e	8.3±0.00058c	8±0.00058d	9.063±0.00058a	5.8±0.0057f	5.49±0.00058g	7.234±0.00058e
Oleic acid%	46.88±0.00058c	44.4±0.00058e	47.48±0.00058b	41.43±0.00058g	40.15±0.00058h	44.05±0.0057f	45.15±0.00058d	52.09±0.00058a
Linoleic acid%	25.45±0.0057c	24.99±0.00058d	28.14±0.00058b	40.56±0.00058a	24.98±0.00058d	15.95±0.0057g	20.06±0.006e	18.83±0.0058f
Gamma linolenic acid%	8.17±0.00058e	12.39±0.00058d	7.08±0.00058f	0h	6.11±0.00058g	21.76±0.0057a	17.96±0.00058b	14.17±0.00058c
Alpha linolenic acid%	5.17±0.003e	7.56±0.00058b	5.2±0.00058e	0.00058±9 6.d	3.7±0.0006g	7.2±0.0006c	7.67±0.0006a	4.6±0.0006f
Eicosanoic acid%	0.24±0.0006e	0f	0.28±0.0006d	0.34±0.0006b	0.28±0.0006d	0f	0.42±0.0003a	0.3±0.0006c
Stearic acid%	0a	0a	0a	0a	0a	0a	0a	0a
Palmitoleic acid%	0c	0c	0c	0c	0c	0.44±0.0006b	0c	0.6±0.0006a

[a] Numbers within each row followed by different small letters are significantly different (P< 0.05).

Table 3. The contents of the fatty acids extracted from different types of pistachio irradiated with gamma (Dose= 5 kGy), after 3 and 6 months of storage.[a]

Cultivar	Ohadi		Akbari		Kaleh Qouchi		Ahmad Aghaei	
	Storage time							
Fatty acid	3 months	6 months	3 months	6 months	3 months	6 months	3 months	6 months
Myristic Acid%	0.09±0.0003b	0.07±0.0005d	0.09±0.0005b	0.07±0.0005d	0.08±0.0005c	0.06±0.0005e	0.1±0.0005a	0.08±0.0005c
Palmitic Acid%	0.0005±9.7a	0.0005±6.9.f	0.0005±9.2b	0.0005±8.2d	0.0005±7.3e	0.0005±6.8f	0.0005±8.9b	0.0005 ± 8.6c
Oleic Acid%	0.0005±57.98c	0.0005±48.2.e	۰۰۳.±۰60.78b	0.0005± 38.79h	0.0005.±44.43f	0.057± 43.8.g	0.0005± 66.65.a	0.003±57.07d
Linoleic Acid%	0.0005±30.50b	0.0005±26.54d	0.0005± 27.16c	0.0005± 35.9a	0.0005± 24.99e	0.0005±18.93g	0.0005± 20.89f	0.0005± 20.51f
Gamma linolenic Acid%	0e	0.0003±9.07d	0e	0e	0.0005± 12.93b	0.0005±18.58a	0e	0.0005 ± 10.53c
Alpha linolenic Acid%	0.0005±0.33e	0.0005±5.85c	0.0003 ± 0.62d	0.0005 ± 0.31e	0.0005 ± 7.56a	0.0005±7.1b	0f	0f
Eicosanoic acid%	0.0005±0.38b	0.0005±0.35c	0.0005± 0.41a	0.0005± 0.38b	0f	0.0005±0.13e	0.0005 ± 0.23d	0.0005 ± 0.39b
Stearic Acid%	0a	0a	0a	0a	0a	0a	0a	0a

[a] Numbers within each row followed by different small letters are significantly different (P< 0.05).

except Kaleh Qouchi, yet over time, it decreased in all types. Linoleic acid had significant changes.

According to Table 4, the increase of gamma dose to 9 kGy decreased the oleic acid, playing a major role in the creation of derived fatty acids that benefit human health. Although, gamma linolenic acid was high in Ohadi, Akbari, and Kaleh Qouchi during the first three months, it became zero at the end of the six months. Only in Ahmad Aghaei, gamma linolenic acid increased over times due to the variety of its physical properties. During the six months, stearic acid was not observed in the pistachios. After six months, Palmitoleic acid was observed in all of the pistachios, irradiated by 9 kGy dose of gamma. As the gamma dose increased, Palmitic acid decreased in the Ohadi, Kaleh Qouchi and Ahmad Aghaei pistachios, but it increased in the Akbari pistachios. Gamma-linoleic and Alpha-linoleic acid were also produced less in the Ohadi and Kaleh Qouchi pistachios. Irradiation changed oleic (C18:1) and linoleic acid (C18:2) in the pistachio oil, including the decrease of oleic acid (C18:1) and increase of linoleic acid (C18:2). The other fatty acids remained unchanged after the irradiation (Ozcan, 2009). This is in line with the findings of this research. Such changes are a variable of the variety of pistachio. Furthermore, in the control samples, in all pistachio types, linoleic acid was the same and had no significant change. After the six months, the greatest abundance of this acid was observed in the Akbari pistachios irradiated with 3, 5, and 9 kGy doses of gamma, and in the Ohadi pistachios irradiated with 9 kGy dose of gamma. Al-Bachir (2004) showed fatty acids increase in grains right after irradiation, which could be due to the decomposition of big molecules of lipids and the production of small molecules such as free fatty acids. Also, Al-Bachir (2014) confirmed the role of gamma irradiation in modifying the amount of oleic acid and linoleic acid in pistachios. He found that irradiation increased linoleic acid and decreased oleic acid, and there was no significant change in other fatty acids. Golge and Ova (2008) revealed that 5 kGy gamma irradiation had significant impact on palmitic, stearic, oleic and linoleic acids (Sig. level= 5%). Gamma dose of 0-3 kGy irradiation had no significant impact on the profile of fatty acids. However, gamma irradiation produces free radicals, and anti-oxidants could absorb radicals in food nutrients (Golge and Ova 2008). Gecgel *et al.* (2011) found that the increase in gamma dose from 0.5 to 2 kGy increased fatty acids in walnuts. It was also found that oleic acid in irradiated nuts such as pistachio, almond, walnut and hazelnut was less than oleic acid in the control samples; this difference was raised by increasing the irradiation dose. Only in the irradiated walnuts, oleic acid was more than the control sample, which is mainly due to the existence of greater linoleic acid in walnut compared to hazelnut, pistachio and almond (Gecgel *et al*., 2011). Saturated fatty acids in the irradiated samples were less than that of the control samples. Linoleic acid was reduced after the irradiation in pistachio and walnut because irradiation of fatty acids led to the creation of two types of long chain hydrocarbons. The first type has one and the second type has two carbon atoms more than the original fatty acid. The rise of gamma irradiation to 7 kGy increases saturated fatty acids and decreases monounsaturated and polyunsaturated fatty acids (Gecgel *et al*., 2011).

Table 5 shows that oleic fatty acid decreased significantly in all of the pistachio types after the irradiation. According to Table 5, the amount of irradiation in the amount of myristic fatty acid was not significant ($F_{3, 186}$= 1.089, Sig.= 0.355). Also, the dose rate was effective in palmitic fatty acid, and this effect was significant ($F_{3, 192}$= 100.75, P< 0.00). Different doses of irradiation were significant on the amount of oleic acid ($F_{3, 192}$= 14.97, Sig.= 0.00). Different doses of irradiation were significant on the amount of linoleic acid ($F_{3, 192}$= 5.78, Sig.= 0.00). For gamma-linoleic acid fatty acids, the dose rate was not significant ($F_{3, 93}$= 1.74, Sig.= 0.18). There was a significant difference in fatty acid content of alpha-linoleic acid with regard to the amount of irradiation (F3,

Table 4. The contents of the fatty acids extracted from different types of pistachio irradiated with gamma (dose= 9 kGy), after 3 and 6 months of storage.[a]

Cultivar	Ohadi		Akbari		Kaleh Qouchi		Ahmad Aghaei	
	Storage time							
Fatty acid	3 months	6 months	3 months	6 months		3 months	6 months	3 months
Myristic acid%	0.0005± 0.08 b	0.0005± 0.08 b	0.0003 ± 0.07 c	0.0003 ± 0.07 c	0.0005± 0.08 b	0.0005± 0.07 c	0.0005± 0.09 a	0.0005 ± 0.06 d
Palmitic acid%	0.0005± 8.43 c	0.0005± 8.02 d	0.0005± 7.43 g	0.0005 ±7.51 f	0.0005± 9.23 a	0.0005 ± 8.69 b	0.0005± 7.66 e	0.0005 ± 6.93 h
Oleic acid%	0.0005± 38.36 f	0.0005± 39.9 e	0.0005± 23.93 g	0.0005± 47.01 d	0.0005± 39.87 e	0.0005± 53.77 b	0.0005± 59.9 a	0.01± 48.17 c
Linoleic acid%	0.003 ±29.83 d	0.005± 40.49 a	0.0005± 29 e	0.005± 36.75 b	0.0005 ± 25.9 f	0.005± 31.53 c	0.005 ± 17.12 h	0.005± 23.13 g
Gamma linolenic acid%	0.0008± 7.03 e	0f	0.0005± 8.96 c	0 f	0.0005±7.20d	0 f	0.0005± 9.43 b	0.005 ± 12.91 a
Alpha linolenic acid%	0.0005 ± 5.35 e	0.0005 ± 7.68 a	0.0005 ± 6.78 b	0.0005 ± 6.07 d	0.0005± 4.53 f	0.0005 ± 3.58 g	0.0003± 2.96 h	0.0005± 6.13 c
Eicosanoic acid%	0.0005 ±0.27 e	0.0005 ± 0.21 f	0.0005± 0.31 d	0.0005 ± 0.4 a	0.0005 ± 0.27e	0.005 ± 0.33 c	0. 005 ± 0.37 b	0.0005 ± 0.08 g
Stearic acid%	0 a	0 a	0 a	0 a	0 a	0 a	0 a	0 a
Palmitoleic acid%	0 e	0.0005± 0.82 a	0 e	0.005± 0.53 c	0 e	0.0005± 0.79 b	0 e	0.0005± 0.51 d

[a] Numbers within each row followed by different small letters are significantly different (P< 0.05).

Table 5. Total comparison of fatty acid index (myristic acid, palmitic acid, oleic acid, linoleic acid, gamma linolenic acid, alpha linolenic acid and eicosanoic acid) in irradiation treatments.[a]

Irradiation	Myristic acid%	Palmitic acid%	Oleic acid%	Linoleic acid%	Gamma linolenic acid%	Alpha linolenic acid%	Eicosanoic acid%
control	0.12±0.01a	9.72±0.92a	52.96±18.21a	27.24±0.26 bc	-	0.42±0.1 d	0.36±0.08a
3 kGy	0.12±0.19a	7.47±1.10a	43.05±11.96c	26.14±6.68 c	11/94±5/89a	6.38±1.78a	0.29±0.05b
5 kGy	0.08±0.01a	8.48±0.90a	53.93±7.06 a	27.99±5.37 ab	10/95±4/12a	3.45±2.66c	0.37±0.08a
9 kGy	0/11±0.15a	7.83±0.77b	47.80±5.58 b	29.06±6.28a	9/68±4/39 a	5.52±2.00b	0.30±0.11b

[a] In each column or row???, different small letters denote significant differences at P< 0.05

183= 148.96, Sig.= 0.00). The irradiation dose affected the amount of eicosanoic acid, and there was a significant difference (F3, 171= 9.24, P< 0.00).

CONCLUSIONS

This research focused on the fatty acid compounds of irradiated pistachios with 3, 5, and 9 kGy doses of gamma. It was found that the dose and storage duration have an impact on the acids compounds. Unsaturated fatty acids such as oleic and linoleic acids are important in nutrition. Of course, gamma-linoleic and alpha-linoleic acid fatty acids derived from fatty acids are present in a small number of foods that are very important in nutrition (The British Nutrition Foundation, 2013). Therefore, it can be concluded that the use of irradiation doses of 5 and 9 kGy affect the increase of these fatty acids, and because of lower irradiation, the dose of 5 kGy is most appropriate.

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تاثیر پرتودهی اشعه گاما بر پروفایل اسید چرب انواع مختلف پسته در استان کرمان

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چکیده

یکی از راه های نگهداری مواد غذایی، استفاده از اشعه گاما است. اشعه گاما بر میزان و نوع اسید های چرب مواد غذایی موثر است، لذا، در این تحقیق تأثیر استفاده از اشعه گاما در پسته نگهداری شده برای مدت شش ماه و تعیین دز مناسب اشعه گاما بدون تاثیر منفی بر میزان اسیدهای چرب در انواع مختلف پسته مورد بررسی قرار گرفت. سه دوز ۳، ۵ و ۹ کیلوگری اشعه گاما استفاده شد. پس از قرار گرفتن در معرض اشعه گاما، پسته ها به مدت شش ماه در یک انبار با دمای ۵ درجه سانتی گراد و رطوبت نسبی (۴۳-۹ درصد) نگهداری شدند. هر سه ماه نمونه ها مورد آزمایش قرار گرفتند. نتایج نشان داد که بیشترین مقدار اسید اولئیک در نمونه های بدون اشعه دهی به ترتیب در رقم احمد آقایی (۶۳/۲۲ درصد) ، اوحدی (۶۱/۰۳ درصد)، کله قوچی (۵۹/۸۳درصد) و اکبری (۵۵/۸۰درصد) بود ($p<0.05$). با گذشت زمان، اسید اولئیک و اسیدهای چرب غیر اشباع در تمام نمونه های شاهد و اشعه داده شده، کاهش یافت. پس ازسه ماه نگهداری، در پسته احمد آقایی اشعه داده شده با دز ۳ کیلوگری، مقدار اسید چرب اولئیک اسید ۴۵/۱۵٪، با دز پنج کیلوگری پس از سه ماه، ۶۶/۶۵٪ و با دز ۹ کیلوگری پس از سه ماه، ۵۹/۹۰٪ بود. افزایش دز اشعه گاما منجر به کاهش اسیدهای چرب غیر اشباع و افزایش اسید های چرب غیر اشباع مشتق شده گردید. استفاده از اشعه گاما در دزهای ۵ و ۹ کیلوگری در افزایش کیفیت پسته از نظر ترکیبات اسید های چرب مهم است، ولی چون هر چه میزان دز اشعه دهی کمتر باشد در صنعت غذا بهتر است مناسب ترین دز اشعه ۵ انتخاب می شود.

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