Journal of Nuts

Journal homepage: ijnrs.damghaniau.ac.ir

Investigating the Effects of Storage Time on Fats, Carbohydrates, Proteins, Taste, Color, and Texture Attributes of Roasted Pistachios by Two Fixed and Rotary Methods

Ahmad Shakerardakani[*1], Mahin Rahdari[2,3]

[1] *Pistachio Research Center, Horticultural Sciences Research Institute, Agricultural Research, Education and Extension Organization (AREEO), Rafsanjan, Iran*

[2] *Master of Science in Food Science & Technology, Department of Agriculture, Kar Higher Education Institute, Rafsanjan, Iran*

[3] *Pistachio Safety Research Center, Rafsanjan University of Medical Sciences, Rafsanjan, Iran*

A R T I C L E I N F O

Keywords:

Quality;
Roasted pistachio;
Sensory characteristic;
Storage time

A B S T R A C T

Roasted pistachios are among the most delicious nuts in the world. In addition to their pleasant taste, they have significant nutritional and antioxidant effects. This study aims to evaluate the nutritional, sensory, color, and texture attributes of roasted pistachio nuts using fixed and rotary methods at 160 °C during three storage times of 0, 3, and 6 months, at the ambient temperature (20±2°C). The results showed that the moisture percentage of the samples decreased and increased after the roasting process and during the 6-month period of storage, respectively. The available fat percentage of the samples showed no significant change after roasting and storage. The protein content of the roasted samples declined because of the Maillard reaction. Although carbohydrates are less sensitive to temperature than proteins, after the roasting process, the sugar and starch content of the pistachio nuts decreased. Due to the thermal process, the texture was more fragile, and the hardness of the samples decreased. Because of the caramelization and browning reactions that happened during the roasting process, the color of the samples turned dark and less green. These changes intensified after the 6 months of storage. According to the results, quality changes were not significant in the two methods of roasting and storage ($p \leq 0.05$). Also the temperature and storage time had no specific destructive effect on the nutritional, sensory, color and texture properties of roasted pistachios. Therefore, the use of these two methods of roasting at 160℃ for 15 minutes is recommended.

Introduction

Nuts are important sources of nutrients, unsaturated fats and proteins and when used either roasted or raw are useful for health (Ros, 2010). In recent decades nuts consumption increased due to their availability and increase in nutritional features awareness (O'Neil *et al*., 2010). Pistachio is a grain nutty from pistachio tree (*Pistacia vera* L.). Pistachio that is one of the popular nuts in the world that is known as the green gold

[*]**Corresponding author**: Email address: shaker@pri.ir
Received: 21 May 2019; Received in revised form: 19 February 2020; Accepted: 16 May 2020
DOI: 10.22034/jon.2020.1869376.1056

because of its high economic value. It is the most important agricultural product that is produced in some arid and semi-arid areas of countries, such as Iran, USA, Syria and Turkey (Sharifkhah *et al*., 2020; Eslami *et al*., 2019; Hsu *et al*., 1991). Among these countries, Iran is one of the biggest producer of pistachio in the world that is ranked second in pistachio production (Norozi *et al*., 2019). Pistachio is noticed in many communities due to its mineral contents and health promoting properties. According to FAO reports, in 2016 pistachio production in Iran stand for 315151 tons that is considered to be as much as non-oil exports. Pistachio is usually used as salty, roasted snack or as ingredients in bakery and confectionery products, desserts and ice cream (Tsantili *et al*., 2010, Shakerardekani *et al.* 2017; Shakerardekani *et al.* 2013). Roasting is a vital step in improving its quality, because in roasting process, aroma, taste, color, texture and appearance of nuts will improve. It was shown that, in this thermal process physical, texture and sensory properties changed and many chemical reactions happened (Nikzadeh and Sedaghat 2008). For example, enzymes and adverse microorganism activity reduced during the roasting process. In addition, roasting affected lipids, carbohydrates, amino acids, moisture, color, and texture of pistachio nuts, and as a result free fatty acids increased. Total pistachio carbohydrate amount and also moisture content reduced and resulted in pigment compositions and desirable flavor. Roasting process increased general popularity of products (Kahyaoglu and Kaya 2006; Pittia *et al.*, 2001; Saklar *et al.*, 1999; Kato *et al.*, 1981; Jayalekshmy and Mathew 1990). Products from non-enzyme embrowning, Maillard and Starker, included variety of products with the complex structure that most of them were unsaturated. Dual bands in structure of these compounds attracted light and as a result act similar to brown pigments and participated in creating dark color in roasted product. Enzyme embrowning of sugar, thermal dehydration, and sugar analysis also consequence in producing brown pigments with organic acids and types of aldehydes and ketones (Danehy, 1986; Friedman, 1996; Namiki, 1988; Özdemir and Devres, 2000). Many researchers use color as a quality control indicator because the brown pigments increase with enzyme-embrowning reaction improvements. Accordingly, one could point out to Kahyaoglu and Kaya (2006) in roasting sesame seeds, Özdemir and Devres (2000) in roasting hazelnuts, Mendes *et al* (2001) in roasting coffee seeds, and Kahyaoglu (2008) in roasting pistachio kernels. However, the roasting method improves total acceptance but reduces the nutritional value.

In 2014, Sazgarnia studied the effects of different roasting conditions including temperature (90, 120 and 150°C), time (20, 35 and 50 minutes), physicochemical characteristics, sensory, texture and geometric characteristics of pistachio seeds and kernel. Increasing roasting temperature causes reduction in moisture content, sensory, hardness, breaking power, instrumental hardness and entropy, and increase in bitterness and uniformity in shape of roasted pistachio kernel. Increasing roasting time reduces moisture content of the pistachio kernels. Results of sensory test show roasted pistachio kernels have good acceptance in terms of taste, color and texture. An artificial neural network is able to be used in prediction of geometric characteristics of roasted pistachio kernels. Breaking power, instrumental and sensory hardness, external modulus of elasticity, pressure energy and moisture content have the biggest standard coefficients and more than other cases affected by roasting temperature. Color and flavor characteristics have the biggest standard coefficients and have the most effects on total acceptance of roasted pistachio. Also Mohammadi moghaddam *et al*. (2017) expressed that chemical changes occurred during roasting and drying, caused flavor and taste changes. In this research, the temperature (90, 120, and 150°C), time (35, 20, and 50

min), and air flow velocity (5.0, 5.1, and 5.2 m/s) of roasting were studied on the texture characteristics of pistachio seeds, including the breaking point, hardness, compressive strength, and apparent modulus of elasticity. Increasing the roasting temperature led to a decrease in the breaking point, hardness, and pressure energy of pistachio kernel. An increase in the time and air flow rate of roasting did not exert significant effects on the breaking point, hardness, and pressure energy. In addition, an increase in the temperature, time, and air flow of roasting led to a decrease in the external modulus of elasticity. According to the results, the interaction among the three studied factors of temperature, time, and air flow rate of roasting showed significant effects on the break point.

Dehdashti *et al.*, 2015 studied the effect of different temperatures on color and kinetics of pistachio color. In this research they studied effects of temperatures 120, 140 and 160°C, and duration of 20, 30 and 50 minutes on the roasted pistachio color changes. Quality tests of color are about index changes including L^*, a^*, b^* index of total color changes, Hue angle and embrowning index. Results showed that with the roasting temperature and time rise, all the color indexes changed. The changes in the color of final product were not desirable in consumer point of view. With the temperature rise, the rates of color changes (including embrowning) increased.

Shakerardekani *et al.* (2011), in relation to roasting pistachio for producing pistachio paste declare that recommended temperature and time for producing pistachio paste are respectively 130-140°C for 30 to 40 minutes.

Hojjati *et al.* (2013) roasted 3 types of Ahmad Aghaei, Akbari and Kallehqhoochi pistachio (immersed in saline water, dried and rotated at 135°C) traditionally, and studied characteristics of volatile compounds, color, odor and declared that glossiness of kernels reduced because of Maillard process. In addition, 26 compounds diagnosed in these pistachio and Akbari pistachio had greater smell intensity than the two other varieties.

Nikzadeh and Sedaghat (2008) evaluated the effect of storage time on the moisture, texture and sensory characteristics of roasted pistachios. According to results, hardness and facture force increased during the storage period. In addition, with the increase of storage period, the moisture rate, hardness and fracture reduce significantly. The use of higher temperature in roasting caused less hardness. Results showed that, correlation between sensory characteristic and instrumental results were very important. Therefore, the aim of this study was the evaluation of nutritional, sensory, color and texture of roasted pistachio nuts with fixed and rotary methods at 160 °C for three storage periods of zero, three, and six months.

Materials and Methods

The Fandoghi pistachio samples were prepared from Jalal Abad processing unit (Sirjan, Kerman province). The sun dried raw pistachios (3 kg) were roasted in 160°C for 15 minutes in rotary roasting machine (Tabriz, construction of Iran). The roasting process was carried out at Jalalabad Pistachio Terminal roasting company (Sirjan, Iran). 4 kg of raw samples were roasted in laboratory oven (UNB 400, Memmert, Germany) with 160°C for 15 minutes that is considered as fixed roasting method. After roasting, all the pistachios cooled in ambient temperature. The moisture, sensory, color and texture features of roasted pistachio nuts was measured at 0, 3 and 6 months of storage.

Nutritional characteristics

Moisture measurement

The available free water in the roasted samples was determined using their weight reduction after drying them in an oven using the method introduced in the book titled “Current Protocols in Food Analytical

Chemistry (Wrolstad *et al.*, 2001) as well as the ISIRI 627 method. To measure moisture percent, first the oven temperature (UNB 400, Memmert, Germany) was set on 105°C and then Aluminum plate was placed in oven to the number of samples for 1 hour and transferred them to the desiccator for 30 minutes to cool them and to reach the constant weight. Then, the weight (M_1) of empty plate was measured and 3 to 10gr of powder sample was poured in plate and dispersed it completely into plate and its weight (M_2) was measured. Samples were placed in an oven for 4 hours. After this time, the plates were removed from the oven and placed in a desiccator to reach the laboratory temperature. Then, the weight was recorded (M3), finally, the moisture content of the samples was calculated according to the following formula (Eq. 1).

$$\text{Moisture (\%)} = (M_1+M_2) - M_3/M_2\times 100 \qquad \text{Eq.1}$$

Fat percentage

The extraction of oil from the samples was carried out using a Soxhlet machine (Soxtherm S306 AK, Germany) with hexane utilized as the solvent according to the method described by Wrolstad *et al* (2001). About 20 g of pistachio powder weighted and transferred into Soxhlet apparatus. The fat extraction action was continued for 2 hours. Fat percentage was calculated from the equation 2:

$$\text{Fat (\%)} = (M_1+M_2)-M_3/M_2\times 100 \qquad \text{Eq.2}$$

M1 = weight of empty filter paper, M2 = weight of the sample, M3 = filter paper and sample weight after the process

Measurement of the crude protein content by the Kjeldahl method

The crude protein content (Eq.3) was calculated based on the measurement of the total nitrogen in the samples by assuming that all nitrogen is of the protein type; the measurement was carried out using the method introduced by Wrolstad *et al* (2001). The nitrogen conversion factor was considered at 6.25.

$$\text{Protein (\%)} = \text{titration volume} \times 1.4\times 0.1\times 6.25 \times 100/\text{sample weight} \qquad \text{Eq. 3}$$

Measurement of carbohydrate percentages by the DNS method

Glucose is a monomer for the measurement of which a DNS reagent was used. The adsorption of each sample was read by a spectrophotometer with the wavelength of 540 nm. According to the standard curve already obtained as well as the dilution coefficient, the sugar in pistachios was calculated (Eq.4) and reported (Ceirwyn, 1994).

$$\text{The sugar concentration (from the standard curve)} = \text{the real concentration} \times \text{dilution coefficient} \qquad \text{Eq.4}$$

Sensory evaluation

The samples were evaluated by 30 panelists, including 15 males and 15 females aged 25 to 45, at the intervals of 0, 3, and 6 months of storage time in terms of the sensory taste, color, texture, aroma and odor. Six pistachios from each controlled samples with a three-digit code given to the panelists, also fresh water was given them to drink between each detection step and in this way panelists were done by rating each parameter based on five point descriptive Hedonic measure (very like = 5), (like = 4), (neither like nor dislike = 3), (dislike = 2) and (very dislike = 1) (Meilgaard *et al.* 1999).

Color measurement

The color of the roasted pistachios was measured by a colorimeter, and the value of each of the sample's a^*, b^*, and L^* parameters were set. L^* is light indicant and is variant between 0 and 100, and a^* (from green to red)

and b^* (blue to yellow) parameters are color components that are variant between -120 to 120.

Hardness measurement

Hardness was measured using a firmness measuring device (Lutron FG5020, Taiwan) with the probe diameter of 8 mm. The necessary force for creating primary rupture and failure in texture was measured. Half of pistachio kernels placed underneath the apparatus on the flat surface from the higher surface.

Statistical analysis

The variance analysis test (ANOVA) was used for the purpose of statistical data analysis. The Tukey's test from Minitab 16 software was also used to compare the means. The number of the controlled samples was set at 18 using a completely randomized design in the form of a factorial experiment (2 methods, 3 storage times, and 3 repetitions).

Results

Effects of the roasting method and storage time on the moisture percentage of the roasted pistachios

At the end of the drying stage, the samples' moisture decreased to about 5% and after roasting in two roasting devices, it decreased to 0.9-1.1%. As Table 1 shows, the roasted samples' moisture in the fixed method for time 0 absorbed moisture after 3 months and increased significantly. Then, it reached a balanced state with the storage environment, and after this time during the 6 months of storage, there was no significant change in the moisture percentage. In relation to the rotary roasting method, the roasted samples' moisture had no significant difference with the samples of 0 and 3 months of storage. However, after the 6-month storage, the roasted samples' moisture showed a significant increase. The mean comparison of the interactive effect of the roasting method and storage time on the moisture amount was not significant (P= 0.707).

Effects of the roasting method and storage time on the fat percentage of the roasted pistachios

As Table 1 shows, roasting had no significant effect on the samples' fat amount. In addition, the data on the mean comparison of the time interaction effect and the roasting method were not significant (P = 0.064). The results of the present study showed no significant change in the fat percentage of the roasted samples.

Effects of the roasting method and storage time on the roasted pistachios' protein percentage

The mean comparison of the data obtained from the Kjeldahl test showed that the protein percentage of the roasted samples during the six months of storage decreased significantly in the fixed and rotary methods. In contrast, the protein content in the roasted samples did not show any significant difference in the fixed and rotary methods in the three-month period. Also roasting method and storage time interaction showed significant reduction in protein content (P = 0.000). In studied samples, roasted sample in the rotary method had more reduction in protein percent compared to fixed method.

Effects of the roasting method and storage time on the roasted pistachios' carbohydrate percentage

The mean comparison of the data obtained from the roasting method and storage time (Table 1) showed that the carbohydrate percentage of the roasted samples decreased significantly in the fixed method during the six-month storage time. In addition, a significant decrease was observed in the carbohydrate percentage of the roasted samples in the rotary method during the six-month storage time. The study of the samples during the storage time showed that the roasted samples had no significant difference in the fixed method during the six months with the roasted samples in the rotary method

during the six months. However, the interaction between the storage time and the roasting method led to a significant decrease in the carbohydrates (P <0.05).

Table 1. Comparison of the effect of roasting method and storage time on moisture content, fat, protein and carbohydrate.

Sample/storage month	Moisture (%)	Fat (%)	Protein (%)	Carbohydrate (%)
Fixed method				
0	1.08± 0.14 b	20.62±0.25 a	24.96±0.34 b	30.86±0.30 b
3	1.41±0.00 a	19.31±0.29 a	22.23±0.18 c	25.03±0.29 d
6	1.51±0.02 a	21.00±1.41 a	20.91±0.18 d	20.99±0.91 e
Rotary method				
0	1.08±0.17 b	31.39±0.29 b	26.44±0.43 a	35.80±0.69 a
3	1.35±0.07 b	31.35± 0.49 b	22.290.19 c	28.62±0.54 c
6	1.56±0.12 a	29.95±0.85 b	20.77±0.04 d	19.27±1.02 e

Note: *Different letters show significance difference (P<0.05); ± Standard error

Effects of the roasting method and the storage time on the roasted pistachios' sensory characteristics

After the study of the interaction mean comparison of the data from the sensory evaluation of the roasted samples stored during different durations (Table 2), the panelists declared that the roasting method and the storage time were significantly different in color, odor, and taste, but there was no significant difference among them in crispiness. Besides, in relation to the color of roasted samples , the roasted sample in the rotary method, during the six-month period, showed a significant difference compared with other samples.

In relation to crispiness of roasted sample in 0 storage time with the samples of three and six months storage time in fixed method and six months of rotary method had significant difference but with roasted samples in rotary method of 0 and 3 months storage didn't have significant difference. Odor and taste in roasted samples in 0 and 3 months duration of storage in two fixed and rotary methods compared to each other didn't have significant difference, and just stored samples in 6 months storage in two methods had significant difference compared to other times of storage. Taste also in roasted samples in fixed method had significant decrease, while taste of roasted samples in 0 time and 3 months storage time in rotary method had no significant decrease and was significant just in six months storage time.

Also roasted sample in six months' time in both roasted samples of fixed and rotary didn't have significant difference in terms of taste and also roasted sample with fixed method of three months storage time didn't show significant difference with the roasted samples in six months storage time.

Table 2. Comparison of the effect of roasting method and storage time on sensory characteristics

Sample/storage month	Color	Hardness	Odor	Taste
Fixed method				
0	4.36±0.76 a	4.70±0.53 a	4.20±0.890 a	4.86±0.34 a
3	4.10±0.80 a	4.10±0.75 bcd	4.26±0.58 a	3.10±1.15 c
6	4.26±0.82 a	3.66±0.95 cd	3.46±0.77 b	2.26±0.78 d
Rotary method				
0	4.20±0.76 a	4.53±0.57 ab	4.66±0.47 a	4.20±0.71 b
3	4.46±0.68 a	4.23±0.85 abc	4.16±0.74 a	4.13±0.73 b
6	3.06±0.78 b	3.53±0.81 d	2.73±0.69 c	2.53±0.97 cd

*Different letters show significance difference (P<0.05); ± Standard error

Effects of the roasting method and the storage time on the roasted pistachios' color test

The mean comparison of the two methods of roasting and storage time (Table 3) was not significant in terms of L^*, a^*, and b^* indices. L^* Index decreased in both fixed and rotary methods during the storage time. In addition, the fixed samples of the zero and tree-month storage time as well as the zero and three-month period in the rotary method had no significant difference with each other. Likewise, the fixed samples of the three-month period, the six-month period, and the rotary samples of the six-month period had no significant difference in terms of index L^* (Table 3).

In relation to a^* index no significant change seen in samples. While b^* index in two methods of roasting and storage time had significant reduction. No significant difference was seenn in b^* index in fixed samples of zero and three months storage time samples with each other and fixed of three months and six months compared to each other. But there was significant difference between fixed sample of zero time and fixed of six months. There wasn't significant difference in rotary method of zero and three months storage time. Differences of fixed samples of zero and three months and rotary of zero and three months compared to each other weren't significant and fixed samples of zero and three months and rotary of six months with each other weren't significant.

Table 3. Comparison of the effect of roasting method and storage time on color

	Color		
Sample/storage month	L^*	a^*	b^*
Fixed method			
0	70.42±1.83 a	-11.16±3.31 a	30.831.55 a
3	62.84±1.79 ab	-9.58±2.63 a	28.15±1.61 ab
6	55.40±4.49 b	-8.17±4.9 a	23.80±3.86 bc
Rotary method			
0	72.50±1.37 a	-11.01±2.11 a	29.331.69 a
3	68.031.93 a	-9.23±2.03 a	29.62±0.87 ab
6	55.71±6.57 b	-6.95±0.13 a	22.76±0.85 c

*Different letters show significance difference (P<0.05); ± Standard error

Effects of the roasting method and storage time on the roasted pistachios' hardness

The results of the mean comparison of data on the interaction between the two methods of roasting and storage time (Table 4) did not show a significant difference in the roasted pistachios' hardness (P> 0.05). In the roasting method with the fixed method, the roasted samples' hardness in the zero and three-month periods had no significant change. The change in the six-month period had a significant increase compared to the storage. In addition, in relation to the roasted samples in the rotary method, no significant difference was observed between the roasted samples in the zero and three-month periods of storage. However, hardness showed a significant increase after the six-month storage period of the samples. The fixed samples of the zero time, the fixed samples of the three-month period, and the rotary method of the three-month period had no significant difference with each other. In addition, the fixed method of the zero time with the rotatory method

of zero and the three-month storage time had no significant difference. Besides, the rotary method of six months and the fixed method of three months had no significant difference.

Table 4. Comparison of the effect of the method of roasting and storage time on hardness (N)

Sample	Hardness
Fixed method/storage month	
0	1.13±0.27 cd
3	2.03± 0.43 bc
6	3.83±0.50 a
Rotary method	
0	0.94±0.08d
3	1.490.27 cd
6	2.71±0.38 b

*Different letters show significance difference (P<0.05); ± Standard error

Discussion

Effects of the roasting method and storage time on the moisture percentage of the roasted pistachios

According to the results, the moisture of samples was about 5% at the end of the drying stage, and the moisture of roasted samples decreased from 0.91% to 1.19% after roasting. Therefore, after roasting, moisture of samples was low and during storage time had significant increase. In fact, moisture increase during storage can be related to samples low moisture compared to the air humidity after roasting and storage at room temperature without packaging and finally fast absorption of air humidity. During storage time pistachio's moisture and air humidity balanced and after that had no significant increase. Based on Iran National Standard (No. 15), the maximum amount of moisture in roasted pistachio shouldn't exceed 3 percent. So, the moisture of investigated samples in all three times was in the standard range. In the researches done by Bhattacharya and Prakash, 1997; Kahyaoglu and Kaya, 2006; Nikzadeh and Sedaghat, 2008 according to pea, sesame and pistachio also the storage time was significantly affected moisture content. With increase in storage relative moisture, moisture content was increased (Tavakolipour, 2000).

Effects of the roasting method and storage time on the fat percentage of the roasted pistachios

According to Nikzadeh and Sedaghat (2009), roasting had no effect on total fat, total simple fats and total compound fats. Also the obtained results match with the results of Kamangar *et al*., 1975; Clarke *et al.*, 1976; Kashani and Valadon, 1983.

Effects of the roasting method and storage time on the roasted pistachios' protein percentage

Protein has formed about 20% of the kernel (Kashani, 1982). According to Kashani and Valadon (1984), proteins are sensitive to heat and because of heat with destruction of specific amino-acids, proteins affected, and as a result caused reduction of food nutritional value. Nikzadeh (2008) reported that part of incidence of amino acids compounds may be because of their participation in Maillard reaction.

Effects of the roasting method and storage time on the roasted pistachios' carbohydrate percentage

Carbohydrates are nutritious components that make up to 10% of pistachio kernel. Carbohydrates compared to unstable nutrition like vitamins showed less vulnerability compared to heat. Kashani (1982) declared that after roasting all three compositions carbohydrate,

particularly total free sugar and at the end total available carbohydrate reduced significantly. In effect of roasting the monomer sugars show reduction, while Maltose increased and stachyose and raffinose had no change. Significant reduction in sugars related to reducing sugars; Fructose and Glucose that will almost completely destroy. Since Maltose may produce starch due to hydrolysis, and because the amount of this sugar increases after roasting, can conclude that during roasting hydrolysis of starch happens. Yet no evidence found to testify that raffinose and stachyose directly found in Maillard reaction and to be able to combine with proteins and Amino acids.

Kashani and Valdon (1984) studied the effect of roasting on pistachio and declared that during roasting process, pistachio's sugar and starch was affected and reduced. Also, Rohan and Stewart (1966) studied changes in sugar content in roasted cocoa, they reported complete destruction of dropped sugars. Also they declared that sucrose participated in reaction and hydrolyzed during cocoa seeds roasting.

Oupadissakoon and Young (1984) studied peanut roasting, that sugar content reduced sugar to 0.8%, and sucrose content hydrolyzed. Also Jayalekshmy and Mathew (1990) studied change in carbohydrate and protein amount of coconut during roasting, and declared that total amount of free sugars and on the other hand total carbohydrate significantly reduced after roasting. Also Nikzadeh (2008) approved that common methods of roasting pistachio caused reduction of total available carbohydrate, total free sugar, starch and starch gum and also single sugars affected strongly specially reducing sugars. So we can say part of drop of these compounds may be due to the participation in Maillard reaction. Kader also observed reduction of carbohydrate during storage in 1982 and declared this reduction may be because of proportional respiratory activity with storage place temperature.

Effects of the roasting method and the storage time on the roasted pistachios' sensory characteristics

The roasting caused progress in the nutty seeds taste and as a result increased palatability of product. Monosaccharide and Amino acids that are basic precursor of taste, participated in Maillard reaction, and increase Pyrazine compounds. Because of production of different types of aromatic products with complex structures like Aldehyde and Pyrazine that were results of Maillard and Strecker reaction during roasting, roasting process control in terms of taste was very hard and because of need to complex tools and the time required for analysis costed very much. In general, many of heat and chemical reactions that happen during roasting process improved total sensory quality of seed (Nikzadeh and Sedaghat, 2008).

During study, Nikzadeh *et al.* (2011) results of analysis of data related to total acceptance score of pistachio samples in sensory evaluation confirmed significance of effect of roasting temperature and storage time that had most acceptance for roasted pistachios in zero time, and reduced after three months. According to other panelist's scores analysis, moisture of samples, spiciness and color changes increased. Crispiness didn't show significant change that can declare crispiness of samples reduced because of samples moisture absorption during storage time. While during analysis of data from Maskan and Karatas studies (1999) difference in spiciness, moisture and oil absorption of pistachio wasn't significant.

Khoshnoodinia and Sedaghat (2014) with study of effect of time on sensory characteristics of Ohadi roasted pistachio showed that over time hardness of different samples reduced, however in controlled sample the least amount of hardness happened respectively in zero and end of third month time. Effect of storage time on pistachio taste showed that until the first month of controlled samples there was no significant difference; this shows that to the end of first month of storage of

controlled samples had more total acceptance because of better texture. Even in the second month of storage total acceptance in samples didn't have significant effect. In the third month of storage, the total acceptance was significantly reduced because of increase of spiciness in control samples. Other researches also showed same results about spiciness taste in roasted walnuts and pine nuts (Haq *et al.*, 2013; Mehyar *et al.*, 2012).

Oro *et al*., (2009) studied physical and chemical properties and the ability of American walnut oil storage obtained through the hydraulic pressure and it was found that sensory characteristics of American walnut oil didn't change until 60 days of storage in room temperature in darkness. Bendin *et al.,* 2011 studied sensory quality of sunflower oil extracted by pressure by quantitative and descriptive analysis and found volatile compounds of sunflower oil agreed the presented data by sensory judgment. Sharma *et al.,* 2000 used antioxidants about roasted cashew nuts and showed that total acceptance of samples during storage time reduced. But this process was more agreeable about the samples with antioxidants and after 5 months this sample had negligible reduction in total acceptance. In sensory test, roasted pistachios in zero time (exactly after roasting) showed the most acceptance amount that this point during 6 months showed reduction.

Effects of the roasting method and the storage time on the roasted pistachios' color test

Conditions of total roasting of pistachio seed should be controlled specifically; because, not only help the development of taste and odor but also are effective on pistachio's final product's color (Cammarn *et al.*, 1990). Roasting by non-enzyme browning reaction caused pigment increase. Color is one of the most important apparent characteristics of food that causes total palatability increase of product (Maskan, 2001). In addition to increase in consumers acceptance, color was noticed for roasting process control that controlled by color degree. Because brown pigments increased during browning reactions and Caramelization (Saklar *et al.*, 1999: Sena *et al.*, 2001). The products from non-enzyme browning reaction, Maillard and Strecker, included variety of products with complex structures that most of them were unsaturated.

Dual bands in these structures attracted light, as a result, treated the same as brown pigments and participated in creating dark color of roasted product. Sugar Caramelization, thermal dehydration and sugar analysis also caused production of brown pigments with organic acids and various aldehyde and ketones (Özdemir, 2001).

Index L^* showed brightness within the range of 0 and 100, with a^* and b^* having been the color coordinates of green-red and blue-yellow coordinates, respectively. Regarding index a^*, positive amounts were considered as red colors, and negative amounts were considered as green colors, while the positive amount of b^* was related to yellow colors and negative amounts to blue colors (Minolta, 1994). The observed reduction of unit L^* was because of the browning reactions which turned the nuts darker (Severini *et al.*, 2000).

Hojjati *et al.*, 2013 with the study of roasting effect on color and volatile compound of pistachio declared that seeds' brightness reduced during roasting process that is done because of Maillard reaction. In storage time significant change was seen in L^* index. In the studies done according to walnut, the temperature effect and packing space on total antioxidants and walnut pigments during L^* index storage reduced (Christopoulos and Tsantili, 2011). During storage, L^* had a reduction process that is indicative of browning process evaluation and weaken the seeds quality. Effect of storage time on color (Koyuncu *et al.*, 2003 and Lopez *et al.*, 1995) matched the walnut browning and products browning mainly depends on phenols chemical or enzyme oxidation (Christopoulos *et al.*, 2008).

On the other hand, a^* green-red color coordinated in roasted samples had significantly increased. This increase universally showed that during roasting, green intensity reduced in samples, while red intensity increased. Pistachios b^* amount reduced significantly during processing which showed less yellow color. This observed color changes less desirable. The same process reported by Pumillia *et al.*, 2014 during studying the changes in chlorophyll, chlorophyll analysis products and Lutein in roasted pistachios seed and also L^*, b^* and a^* for pistachio oil roasted in 180°C for 5, 10, 20, 30, and 40 minutes (Durmaz and Gökmen, 2011).

Tstantili *et al*., (2010) reported fresh pistachios color (shell, kernel membrane, and inner part of seeds) coordinates compared to physical, composition and sensory figures in various figures of pistachio from Greece. According to the investigated samples in this study declared brightness amounts matched with the expressed information from Iran's pistachio (shell, kernel membrane, and inner part of seeds).

But modeling of moisture, color and tissue changes in sesame seeds didn't correspond with the results of this study during roasting process (Kahyaoglu and Kaya, 2006). In addition roasting conditions effect on color changes reported by other researches like Cämmerer and Kroh (2009) peanut, Özdemir *et al.,* 2001; Özdemir and Devres (2000) huzelnut, Kahyaoglu and Kaya (2006) sesame seed and Wall and Gentry (2007).

Effects of the roasting method and storage time on the roasted pistachios' hardness

Comparison of mean texture changes during six months had the same results with researches done by other researches. Crispiness was a major attribute in kernel evaluation. This texture characteristic was in undeformation materials that were easily and suddenly breakable, and were related to textures mechanical characteristics. This texture characteristic caused the kernels to be more delicious and more desirable to consume (Özdemir, 2001). Roasting nus in low temperatures caused gradual penetration of heat in kernel, without burning the nuts surface. As a result, moisture hardness and crispiness of kernels reduced.

These findings correspond with Nikzadeh and Sedaghat studies (2008) that its inverse relationship observed between roasted temperature and hardness of pistachio. Hardness amount reduction with roasting time increase also showed by (Kahyaoglu and Kaya, 2006) for sesame seeds. Obtained data from this study showed that with roasting; moisture, hardness and breakage had significant reduction. Mean comparison of data showed that texture changes in roasted pistachio during storage time were significant. Also hardness force and breakage and firmness increased during storage time. According to the studies done by Edalatian *et al.*, (2007) and Sedaghat *et al.,* (2006) it was determined that with increase in temperature, the pistachios hardness reduced and roasted pistachios texture changed during storage. One of the main reasons of it can be their moisture increase during this period. Also during storage time fat oxidation increased, so in addition to peroxide and free radicals of fat increase, their distractive products like Aldehydes also increased that all these oxidation products were able to react with vitamins, amino acids and proteins. As a result, in addition to staleness creation, it caused hardness of texture (St. Angelo and Ory, 1975; Senter *et al.,* 1984; Gardner, 1979). Also Raee *et al.,* 2007 showed that, the most and the least hardness was obtained respectively after three months and twelve months from roasted pistachios storage by using machine. Reduction in hardness amount of samples because of high-temperature of roasting reported by other researchers (Mohammadi moghadam *et al*., 2017; Shakerardakani, 2011). Also according to walnut during storage, moisture increased slightly, in addition, hardness of walnut textures also increased (AgnieszkaKita, 2007).

Conclusions

Pistachios are important sources of nutrients, unsaturated fats, and proteins, so using them in both roasted and raw forms could be useful for human health. However, the heat process and storage time could change their moisture, texture, color, and chemical content, including proteins and fats. During roasting, the content of moisture, proteins, and carbohydrates decreases. Due to the desirable changes occurred in terms of taste, color, and hardness in the samples, roasting in fixed and rotary methods could be desirable in both storage times (3 and 6 months). According to the results of the study, all important reviewed parameters were within the standard range. At the end, it is suggested to use these two roasting methods (fixed and rotary) under the roasting conditions of 160 °C for 15 min.

Acknowledgements

The authors would like to thank Iran Pistachio Research Center for the facilities that make this work possible.

References

AgnieszkaKita A (2007) Effect of storage time on texture and selected properties of walnuts. Acta Agrophysica. 9(1), 69-78.

Bhattacharya S, Prakash M (1997) Kinetics of roasting of split chickpea (*Cicer arietinum*). International Journal of Food Science & Technology. 32(1), 81-84.

Cammarn SR, Lange TJ, Beckett GD (1990) Continuous fluidized-bed roasting. Chemical Engineering Progress. 86(6), 40-46.

Cämmerer B, Kroh LW (2009) Shelf life of linseeds and peanuts in relation to roasting. LWT-Food Science and Technology. 42(2), 545-549.

Ceirwyn SJ (1994) Analytical chemistry of foods. Springer-Verlag US. pp,71-135.

Christopoulos MV, Tsantili E (2011) Effects of temperature and packaging atmosphere on total antioxidants and colour of walnut (*Juglans regia L.*) kernels during storage. Scientia Horticulturae. 131, 49-57.

Christopoulos MV, Tsantili E, Papageorgiou V, Komaitis M, Rouskas D (2008) Effects of package atmosphere and temperature on phenolics, total antioxidant capacity and colour in kernels of 'Franquette' walnuts during 8-month storage. In III International Conference Postharvest Unlimited 2008 858. pp. 75-81.

Clarke JA, Brar GS, & Procopiou J (1976) Fatty acid, carbohydrate and amino acid composition of pistachio (*Pistacia vera*) kernels. Qualitas Plantarum. 25(3-4), 219-225.

Crampton EW, Common RH, Pritchard ET & Farmer FA (1956). Studies to determine the nature of the damage to the nutritive value of some vegetable oils from heat treatment: IV. Ethyl Esters of Heat-Polymerized Linseed, Soybean and Sunflower Seed Oils. Journal of Nutrition. 60(1), 13-24.

Danehy JP (1986) Maillard reactions: nonenzymatic browning in food systems with special reference to the development of flavor. In Advances in Food Research. Academic Press. 30, 77-138.

Dehdashti A, Hojjatoleslami M, Shaker Ardakani A, Karimi B (2015) Effect of different temperatures of roasting on the color and kinetics of pistachio in the collection of articles of the 23rd National Congress of Food and Science of Iran, Qhoochan, Oct. 23, 2011, Islamic Azad University, Qhoochan Branch.

Durmaz G, Gökmen V (2011) Changes in oxidative stability, antioxidant capacity and

phytochemical composition of Pistacia terebinthus oil with roasting. Food Chemistry. 128(2), 410-414.

Edalatian M, Sedaghat N, Sharif A (2007) Effects of temperature, packaging and storage on texture of pistachio nuts (Ohadi) and comparision with sensory properties. 1st Iranian. Congress on Processing & Packaging of Pistachio Nuts. 4 &5 Dec 2007. Ferdowsi University of Mashad.

Eslami M, Nasibi F, Manouchehri Kalantari K, Khezri M, Oloumi H (2019) Effect of exogenous application of l-arginine and sodium nitroprusside on fruit abscission and physiological disorders of pistachio (*Pistacia vera* L.) Scions. International Journal of Horticultural Science and Technology. 6(1), 51-62.

Food and Agriculture Organization, FAOSTAT data (2016) Available athttp://faostat.fao.org/site/339/default.aspx.

Friedman M (1996) Food browning and its prevention: an overview. Journal of Agricultural and Food Chemistry. 44(3), 631-653.

Gardner HW (1979) Lipid hydro peroxide reactivity with proteins and amino acids: a review. Journal of Agricultural and Food Chemistry. 27(2), 220-229.

Haq MA, Alam MJ, Hasnain A (2013) Gum Cordia: A novel edible coating to increase the shelf life of Chilgoza (*Pinus gerardiana*). LWT-Food Science and Technology. 50(1), 306-311.

Hojjati M, Calín-Sánchez A, Razavi SH, Carbonell-Barrachina Á (2013) Effect of roasting on colour and volatile composition of pistachios (*Pistacia vera* L.). International Journal of Food Science & Technology. 48(2), 437-443.

Hsu MH, Mannapperuma JD, Singh RP (1991) Physical and thermal properties of pistachios. Journal of Agricultural Engineering Research. 49, 311-321.

ISIRI (2015) Dry fruits- Determination of the moisture content- test methods (627). Karaj: Institute of Standards and Industrial Research of Iran.

ISIRI (2013) Natural Open Pistachio–Specifications (15). Karaj: Institute of Standards and Industrial Research of Iran.

Jayalekshmy A, Mathew AG (1990) Changes in the carbohydrates and proteins of coconut during roasting. Food Chemistry. 37(2), 123-134.

Kader AA, Heintz CM, Labavitch JM, Rae HL (1982) Studies related to the description and evaluation of pistachio nut quality. Journal of the American Society for Horticultural Science. 107(5), 812-816.

Kahyaoglu T (2008) Optimization of the pistachio nut roasting process using response surface methodology and gene expression programming. LWT-Food Science and Technology. 41(1), 26-33.

Kahyaoglu T, Kaya S (2006) Modeling of moisture, color and texture changes in sesame seeds during the conventional roasting. Journal of Food Engineering. 75(2), 167-177.

Kamangar T, Farrohi F, Mehran M (1975) Characteristics of pistachio kernel oils from Iranian cultivars. Journal of the American Oil Chemists' Society. 52(12), 512-513.

Kashani G, Valadon LRG (1983) Effect of salting and roasting on the lipids of Iranian pistachio kernels. International Journal of Food Science & Technology. 18(4), 461-467.

Kashani GG (1982) The effect of roasting and of gamma irradiation on various chemical constituents of six varieties of Iranian pistachio nuts (Doctoral dissertation).

Kashani GG, Valadon LG (1984) Effect of salting and roasting on the carbohydrates and proteins of

Iranian pistachio kernels. International Journal of Food Science & Technology. 19(2), 247-253.

Kato H, Doi Y, Tsugita T, Kosai K, Kamiya T, Kurata T (1981) Changes in volatile flavour components of soybeans during roasting. Food Chemistry. 7(2), 87-94.

Khoshnoodinia S, Sedaghat N (2014). The effect of oral antioxidant-containing gelatin coating on oxidative stability and sensory properties of ovida pistachio seedlings. Iranian Journal of Nutrition and Food Technology. 9(1), 11-20.

Koyuncu MA, Koyuncu F, Bakir N (2003) Selected drying conditions and storage period and quality of walnut selections. Journal of Food Processing and Preservation. 27(2), 87-99.

Lopez A, Pique MT, Romero A, Aleta N (1995) Influence of cold-storage conditions on the quality of unshelled walnuts. International Journal of Refrigeration. 18(8), 544-549.

Maskan M (2001) Kinetics of colour change of kiwifruits during hot air and microwave drying. Journal of food Engineering. 48(2), 169-175.

Maskan M, Karataş Ş (1999) Storage stability of whole-split pistachio nuts (*Pistachia vera* L.) at various conditions. Food Chemistry. 66(2), 227-233.

Meilgaard M, Civille GV, Carr BT (1999) Sensory Evaluation Techniques. Boca Raton: CRC Press. pp,141-171.

Mehyar GF, Al-Ismail K, Han JH, Chee GW (2012) Characterization of edible coatings consisting of pea starch, whey protein isolate, and carnauba wax and their effects on oil rancidity and sensory properties of walnuts and pine nuts. Journal of Food Science. 77(2), E52-E59.

Mendes LC, de Menezes HC, Aparecida M, Da Silva AP (2001) Optimization of the roasting of robusta coffee (C. *canephora conillon*) using acceptability tests and RSM. Food Quality and Preference. 12(2), 153-162.

Minolta Corporation (1994) precise color communication: color control from feeling to instrumentation. Minolta.

Mohammadi MT, Razavi S, Taghizadeh M & Sazgarnia A (2017). The effect of temperature, time and air velocity of roasting on textural properties of pistachio kernels. 14 (62), 77-87.

Namiki M (1988) Chemistry of Maillard reactions: recent studies on the browning reaction mechanism and the development of antioxidants and mutagens. In Advances in food research. Academic Press. 32, 115-184.

Nikzadeh V, Sedaghat N (2007) Investigating the effects of rooting on chemical properties and chemical composition of pistachios in the collection of articles of the first national conference on pistachio processing and packaging in Mashhad, 13 December and 14 December 2007, Ferdowsi University of Mashhad.

Nikzadeh V, Sedaghat N (2008) Physical and sensory changes in pistachio nuts as affected by roasting temperature and storage. American-Eurasian Journal of Agricultural and Environmental Sciences.4, 478-483.

Nikzadeh V, Sedaghat N (2009) Investigating the effects of roasting temperature, formulation and storage time on the quality characteristics of pistachio oil and its organoleptic characteristics. Science and Food Industry. 6(3), 45-54.

Nikzadeh V, Sedaghat N, Shahidi F (2011) Investigation of moisture, texture and sensory properties of pistachios under the influence of roasting temperature and storage time. Science and Food Industry. 8(1), 101-109.

Norozi M, Valizadeh Kaji B, Karimi R and Nikoogoftar Sedghi M (2019) Effects of foliar application of potassium and zinc on pistachio (*Pistacia vera*

L.) fruit yield. International Journal of Horticultural Science and Technology, 6(1), 113-123.

O'Neil CE, Keast DR, Fulgoni VL, Nicklas TA (2010) Tree nut consumption improves nutrient intake and diet quality in US adults: an analysis of National Health and Nutrition Examination Survey (NHANES) 1999-2004. Asia Pacific Journal of Clinical Nutrition. 19(1), 142-150.

Oro T, Bolini HMA, Arellano DB, Block JM (2009) Physicochemical and sensory quality of crude Brazilian pecan nut oil during storage. Journal of the American Oil Chemists' Society. 86(10), 971-976.

Oupadissakoon C, Young CT (1984) Changes in free amino acids and sugars of peanuts during oil roasting. Peanut Science. 11(1), 6-9.

Özdemir M, Açkurt F, Yildiz M, Biringen G, Gürcan T, Löker M (2001) Effect of roasting on some nutrients of hazelnuts (*Corylus Avellena* L.). Food Chemistry. 73(2), 185-190.

Özdemir M, Devres O (2000) Analysis of color development during roasting of hazelnuts using response surface methodology. Journal of Food Engineering. 45(1), 17-24.

Özdemir M, Devres O (2000) Kinetics of color changes of hazelnuts during roasting. Journal of Food Engineering. 44(1), 31-38.

Pittia P, Dalla Rosa M, Lerici CR (2001) Textural changes of coffee beans as affected by roasting conditions. LWT-Food Science and Technology. 34(3), 168-175.

Raee M, Sedaghat N, Poorazarang H, Hashemi N (2007) Studying the effects of packaging material and modified atmosphere on physicochemical properties of pistachio nuts.1st Iranian Congress on Processing & Packaging of Pistachio Nuts. 4 & 5 Dec 2007. Ferdowsi University of Mashad.

Rohan TA, Stewart T (1966) The precursors of chocolate aroma: changes in the free amino acids during the roasting of cocoa beans. Journal of Food Science. 31(2), 202-205.

Ros E (2010) Health benefits of nut consumption. Nutrients. 2(7), 652-682.

Saklar S, Ungan S, Katnas S (1999) Instrumental crispness and crunchiness of roasted hazelnuts and correlations with sensory assessment. Journal of Food Science. 64(6), 1015-1019.

Sazegarnia A (1393) Evaluation of Pistachio Quality Characteristics Using Process Analysis Methods: Empirical Studies and Modeling. Ph.D., Faculty of Agriculture and Natural Resources, Ferdowsi University of Mashhad.

Sedaghat N (2004) Modeling conditions for dry pistachio storage and packaging. Ph.D. of Food Science & Technology, Faculty of Agriculture, Ferdowsi University of Mashhad.

Sedaghat N, Mortazavi A, Nasiri MM, Davarinezhad GH (2006) Prediction shelf life of pistachio nuts at various conditions. Journal of Agricultural Sciences and Natural Resources. 12(6), 127-135.

Sena S, Sinan K, Suat U (2001) Determination of optimum hazelnut roasting conditions. International Journal of Food Science and Technology. 36, 271281

Senter SD, Forbus Jr WR, Nelson SO, Wilson Jr RL, Horvat RJ (1984). Effects of dielectric and steam heating treatments on the storage stability of pecan kernels. Journal of Food Science. 49(3), 893-895.

Severini C, Gomes T, De Pilli T, Romani S, Massini R (2000) Autoxidation of packed almonds as affected by Maillard reaction volatile compounds derived from roasting. Journal of Agricultural and Food Chemistry. 48(10), 4635-4640.

Shakerardekani A, Karim R, Ghazali HM, Chin NL (2011). Effect of roasting conditions on hardness, moisture content and colour of pistachio kernels. International Food Research Journal. 18, 723-729.

Shakerardekani A (2017) Consumer Acceptance and Quantitative Descriptive Analysis of Pistachio Spread. Journal of Agricultural Science and Technology. 19, 85-95.

Shakerardekani A, Karim R, Vaseli N (2013) The effect of processing variables on the quality and acceptability of pistachio milk. Journal of Food Processing and Preservation. 37(5), 541-545.

Shakerardekani A, Karim R, Ghazali HM, Chin NL (2013) Development of pistachio (*Pistacia vera* L.) spread. Journal of Food Science. 78(3), S484-S489.

Shakerardekani A, Karim R, Ghazali HM, Chin Nyuk L (2015) Oxidative Stability of Pistachio (*Pistacia vera* L.) Paste and Spreads. Journal of the American Oil Chemists' Society. 92(7), 1015-1021.

Sharifkhah M, Bakhshi D, Pourghayoumi M, Abdi S, Hokmabadi H (2020) Effect of pollination time on yield and antioxidant properties of some pistachio cultivars. International Journal of Horticultural Science and Technology. 7(1), 51-58.

Sharma GK, Semwal AD, Mahesh C, Murthy MCN, Arya SS (2000) Enhancement of the shelf-life of deep fat fried cashewnuts. LWT-Food Science and Technology. 33(3), 173-177.

St. Angelo aj, Ory RL (1975) Effects of lipoperoxides on proteins in raw and processed peanuts. Journal of Agricultural and Food Chemistry. 23(2), 141-146.

Tavakolipour H (2000) Effective factors in dehydration process and storage conditions of pistachio nuts (*Pistacia vera* L.) (Doctoral dissertation, Ph. D. Thesis, Islamic Azad University, Science and Research Branch, Tehran, Iran).

Tsantili E, Takidelli C, Christopoulos MV, Lambrinea E, Rouskas D, Roussos PA (2010) Physical, compositional and sensory differences in nuts among pistachio (*Pistachia vera* L.) varieties. Scientia Horticulturae. 125(4), 562-568.

Wrolstad RE, Acree TE, Decker EA, Penner MH, Reid DS, Schwartz SJ, Shoemaker CF, Smith DM, Sporns P (2001) Current Protocols in Food Analytical Chemistry. New York: Wiley. pp. 371-525.