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Effect of Freezing and Vacuum Packaging on Quality Properties of Pistachio Powder During Storage

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A R T I C L E I N F O

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A B S T R A C T

Pistachio powder is a product used today in confectionery, ice cream, pistachio paste and other foods. Considering the higher rate of spoilage and oxidation in pistachio powder, developing methods to increase the shelf-life of this product is therefore important. In this study the effect of freezing and vacuum packaging on the quality characteristics of pistachio powder during storage was investigated. The effect of packaging conditions (vacuum or air packaging), storage temperature (25°C, -18°C) and storage time (0, 1, 2, 3 and 4 months) on chemical (free fatty acids, acid value, peroxide value), physical (moisture content and color indexes of L^*, a^* and b^*), and sensory (odor, taste, color, texture and overall acceptance) characteristics were studied. The results revealed that the peroxide value, acid value and free fatty acids in frozen and vacuum containers were lower than those packed without vacuum at room temperature. The results of sensory evaluation indicated a significant difference ($p< 0.05$) in samples.The best quality characteristics in terms of odor, taste, and overall acceptance belonged to the pistachio powder packed in vacuum and frozen conditions; however, in terms of texture , the containers packed and stored in ambient conditions showed better results. In all cases, the quality of pistachio powder decreased during the storage period. There was no significant difference between samples in moisture content, color indices of L*, a*, b* and sensory evaluation of color. It was generally found that packaging under vacuum and freezing could increase the shelf life of pistachio powder.

Introduction

Edible nuts, oil, and the byproducts (shells and fat-free press cake) are known to have various bioactive and health promoting ingredients (Hu *et al*., 1998). In most parts of the world, including the Middle East and Asia, edible nuts are cultivated as oil-bearing crops which are a main source of energy containing essential nutrients for a diet as well as phytochemicals (Bonvehi *et al*., 1993) . Many researchers showed that nuts play a significant role in reducing LDL, cardiovascular disease, types of cancer and diabetes (Abbey *et al*., 1994; Alasalvar *et al*., 2003). Considering the content and type of ingredients, pistachio plays nutritionally a significant role in meeting the body needs compared to other nuts such as walnuts, almonds and hazelnuts. The content of fiber, total carbohydrate, unsaturated fats, sodium, potassium and some vitamins is higher in pistachio, so it is a complete source (Wilkinson, 2005).

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The quality of pistachio is affected by fatty acid compounds mainly oleic and linoleic acids (Roozban *et al*., 2006). Unsaturated fatty acids are more susceptible to oxidative changes due to their compound double bonds. Environmental factors affect the level of fat and fatty acids in pistachio (Agar *et al*., 1997). Thus, in case of suitable environmental conditions (e.g. temperature, relative humidity, and light), degradation reactions such as lipolysis, spontaneous oxidation, optical oxidation and enzymatic oxidation are initiated and free radicals are formed. The production of such radicals, as well as side compounds such as free fatty acids, hydroxides, aldehydes, ketones and alcohols allows analytical reactions in pistachios leading to an unpleasant taste and smell, such as a rancid taste (Maskan and Karatas, 1999). The most recent method controlling oxidation reactions are reducing the oxygen content of the storage atmosphere by altering the combination of storage space (controlled atmosphere storage) or introducing inert gases in packing (modified atmosphere packaging).

The changes in texture and taste is influenced by the storage temperature, time, and oxygen content (Sedaghat, 2006). On the other hand, suitable packaging helps preserve food from spoilage factors, particulary the external spoilage (oxygen, moisture, light, fungi, insects, etc.) and significantly increases the shelf-life of the product (Sedaghat, 2004).

The effects of storage conditions on quality indices during storage were investigated by researchers. In a study, it was found that with proper packing, pistachio can be preserved from spoilage factors, particulary the external spoilage (oxygen, moisture, light, fungi, insects, etc.) and significantly increases the shelf-life of the product (Sedaghat, 2004). Another study revealed that pistachios packed under normal air conditions showed higher peroxide index than vacuum packed ones (Sedaghat *et al*, 2011). The other study, examining the effects of temperature and oxygen concentration on the rate of oxidation reactions in pistachios, discusses that increasing the temperature and concentration of oxygen can increase the speed of oxidation reactions and ultimately leads to spoilage and the production of unpleasant compounds in pistachio powder (Sedaghat *et al*., 2006). The aim of this study was to investigate the effect of vacuum packing and freezing on quality characteristics of pistachio kernel powder such as free fatty acids, acid value, peroxide value, moisture, color indexes and sensory properties during storage for 4 months.

Materials and Methods

Materials

Pistachio

The non split pistachios were selected from Ahmad-Aghaei variety collected from gardens of Rafsanjan in Kerman, Iran.

Chemicals

The chemicals included starch indicator, sodium thiosulfate, acetic acid, chloroform, potassium iodide, n-hexane solvent, phenolphthalein and ethanol provided from Merck (Germany).

Methods

Sample preparation

After breaking the shell, pistachio kernel powder was produced by a semi-industrial grinder. The pistachio kernel powder was divided into two parts. The first part was filled into tin-plated mild steel cans of 250g each, in normal condition. The second part was filled into the same cans under vacuum application (Linger, Iran). The samples were stored at -18 and 25°C for 120 days. At each test period including days of 1, 30,60, 90 and 120, the samples of each group were analysed.

Extraction of pistachio oil

Pistachio oil extraction was performed according to the methods explained by Hashemi *et al*.(2007), Raei *et al*.(2010) and Maskan and Karatas (1998). Pistachio kernel powders were extracted using hexane (at a ratio of 3:1w/w) for 24 h in darkness at ambient temperature. The solvent was evaporated under vacuum at 30ºC.

Tests

Free fatty acids

Free fatty acid was measured by titration and based on the percentage of oleic acid (AOAC, 1990).

Acid value

The acid value was calculated according to Wrolstad *et al*.(2001) Using equation 1 :

$$FFA_{\times} 1.99 = AV \qquad \text{Equation 1}$$

Peroxide value

The peroxide value is defined as the amount of peroxide or active oxygen (meq/kg) per kilogram of oil or fat sample. The peroxide value (in MEq / kg sample) was calculated using Equation 2 (Wrolstad *et al*., 2001). In this equation S is The amount of sodium thiosulfate used in the test (ml), B is The amount of sodium thiosulfate used in the control sample(ml), N is Normality of sodium thiosulfate and W is Oil weight (g).

$$PV = \frac{(S-B)*N*1000}{W} \qquad \text{Equation 2}$$

Moisture content

A mass of 10 g of the pistachio powder was placed in the oven for 5h at 103±2. After drying, the dried sample was weighted and the moisture content was calculated using the percentage of reduced weight (Wrolstad *et al*., 2001).

Color

Color of the samples was determined using the chroma meter model CR-400 (Japan). The factors L^* (white to black), a^* (green to red) and b^* (blue to yellow) were defined by values. Each treatment was sampled during the storage period and, after pouring the sample into a petri dish and smoothing the sample surface, a, b and L indices were read using the device, thus the colors of the samples were defined.

Sensory evaluation

This test was conducted to evaluate some organoleptic characteristics including odor, taste, color, texture/granulation and overall acceptance. Here, 15 semi-trained sensory assessors were employed and the test was performed on the basis of a five-point hedonic scale.

Treatments

Treatments used in this study are shown in Table 1.

Table 1. The Conditions of Pistachio powder packaging

Treatment´s name	Description
S0	The control sample on first day immediately after grinding
AN	Pistachio powder packed in cans under normal air conditions and stored in ambient Temperature
AV	Pistachio powder packed in cans under vacuum and stored in ambient Temperature
FN	Pistachio powder packed in cans under normal air conditions and stored in freezed Temperature
FV	powder pistachios packed in cans under vacuum and stored in freezed Temperature

Data analysis

The tests were conducted in a completely randomized design with three replications. All the Data were analyzed using SPSS version 20 software and graphs were plotted in Microsoft Excel.

Results

Free Fatty Acids (FFA)

The effect of storage temperature and vacuum packaging on amount of free fatty acids in pistachio powder during storage time is shown in Table 2. FFA % was significantly different($p<0.05$) in the samples. The highest content of free fatty acid belonged to AN4 treatment as 3.36% (based on oleic acid), and the lowest FFA% related to FN1 and FV1 treatments, which was 0.35%. The interaction between time and storage temperature also showed a significant difference ($p<0.05$) in free fatty acids. FFA% was significantly increased ($p<0.05$) during the storage period but it was different in various packing conditions, so that in non-vacuumed cans, It happened more quickly.

Table 2. Mean free fatty acid content (% oleic acid) of pistachio powder during storage period

Treatment	First day	First month	Second month	Third month	Fourth month
AN	0.35 ± 0.05^{a}	0.83 ± 0.05^{c}	1.63 ± 0.15^{g}	2.33 ± 0.15^{h}	3.36 ± 0.05^{i}
AV	0.35 ± 0.05^{a}	0.36 ± 0.01^{a}	0.50 ± 0.00^{b}	1.10 ± 0.10^{d}	1.36 ± 0.05^{f}
FN	0.35 ± 0.05^{a}	0.35 ± 0.05^{a}	0.45 ± 0.00^{ab}	1.00 ± 0.00^{d}	1.13 ± 0.05^{e}
FV	0.35 ± 0.05^{a}	0.35 ± 0.00^{a}	0.41 ± 0.01^{ab}	0.50 ± 0.00^{b}	0.50 ± 0.00^{f}

* There are no significant differences between the means of treatments with common acronyms (compared with SPSS software at 5% level)

AN, Pistachio powder packed in cans in non-vacuumed conditions and stored in ambient Temperature ; AV, Pistachio powder packed in vacuumed cans and stored in ambient Temperature; FN, Pistachio powder packed in cans in non-vacuumed conditions and stored in freezed Temperature; FV, powder pistachios packed in vacuumed cans and stored in freezed Temperature.

Acid Value (AV)

As seen in Table 3, packaging type, storage temperature and storage period affected the parameters of pistachio powder significantly ($p < 0.05$). Increasing the storage time and temperature led to increase in the acidity or acid value.The acid value of pistachio powder packed in vacuumed cans was lower than of those packed in non-vacuumed cans. The highest and lowest AV belonged to the samples of AN4 and FV1 that were 6.69 mgKOH/g $\frac{\text{mg KOH}}{\text{gr}}$ and 0.69 mgKOH/g $\frac{\text{mg KOH}}{\text{gr}}$, respectively. It was also observed an acid value of less than 1mg KOH/g after 4 months in freezed and vacuumed filled cans.

Table 3. Mean Acid value of pistachio powder samples during storage period (mgKOH/g ($\frac{\text{mg KOH}}{\text{gr}}$).

Treatment	first day	First month	Second month	Third month	Fourth month
AN	0.69 ± 0.05^{a}	1.65 ± 0.11^{c}	3.24 ± 0.30^{g}	4.63 ± 0.30^{h}	6.69 ± 0.11^{i}
AV	0.69 ± 0.05^{a}	0.71 ± 0.02^{a}	0.99 ± 0.00^{b}	2.18 ± 0.19^{d}	2.71 ± 0.11^{f}
FN	0.69 ± 0.05^{a}	0.70 ± 0.11^{a}	0.81 ± 0.02^{ab}	1.99 ± 0.00^{d}	2.24 ± 0.11^{e}
FV	0.69 ± 0.05^{a}	0.69 ± 0.00^{a}	0.89 ± 0.00^{ab}	0.99 ± 0.00^{b}	0.99 ± 0.00^{b}

* There are no significant differences between the means of treatments with commonacronyms (compared with SPSS software at 5% level) AN, Pistachio powder packed in cans in non-vacuumed conditions and stored in ambient Temperature ; AV, Pistachio powder packed in vacuumed cans and stored in ambient Temperature; FN, Pistachio powder packed in cans in non-vacuumed conditions and stored in freezed Temperature; FV, powder pistachios packed in vacuumed cans and stored in freezed Temperature.

Peroxide Value (PV)

The peroxide values of the pistachio powder samples were different significantly ($p< 0.05$). The pistachio powder filled in non-vacuumed cntainer and stored at ambient temperature had the higher peroxide value as compared to those in vacuumed or freezed packagings (Table 4). The highest and lowest peroxide values observed in samples of AN4(5.5 mEq/kg oil) and FV1 and FV2 (2.5 mEq/kg oil) ,respectively. The higher storage temperature resulted in higher peroxide values but it seems vacuumed or non-vacuumed packaging had more effect on PV.

Table 4. Mean Peroxide Value (mEq/Kg) of pistachio powder during storage period.

Treatment	first day	First month	Second month	Third month	Fourth month
AN	2.50 ± 0.00^{a}	3.03 ± 0.05^{d}	3.93 ± 0.05^{f}	4.63 ± 0.05^{g}	5.50 ± 0.00^{h}
AV	2.50 ± 0.00^{a}	2.53 ± 0.05^{a}	2.70 ± 0.00^{bc}	3.03 ± 0.05^{d}	3.16 ± 0.05^{e}
FN	2.50 ± 0.00^{a}	2.53 ± 0.05^{a}	2.63 ± 0.05^{b}	3.10 ± 0.00^{de}	3.1 ± 0.00^{de}
FV	2.50 ± 0.00^{a}	2.50 ± 0.00^{a}	2.50 ± 0.00^{a}	2.7 ± 0.00^{bc}	2.76 ± 0.05^{c}

* There are no significant differences between the means of treatments with common acronyms (compared with SPSS software at 5% level)
AN, Pistachio powder packed in cans in non-vacuumed conditions and stored in ambient Temperature ; AV, Pistachio powder packed in vacuumed cans and stored in ambient Temperature; FN, Pistachio powder packed in cans in non-vacuumed conditions and stored in freezed Temperature; FV, powder pistachios packed in vacuumed cans and stored in freezed Temperature.

Moisture Content

Effect of three factors (storage temperature , storage period,air) on moisture content of pistachio powders filled in metal cans are shown in Table 5. No significant differences were found at a probability level of 5% ($p< 0.05$). This is probably due to the impenetrability of packaging cans to moisture. The moisture content of the samples in first day was 2.10% and increased slightly to maximum 2.83% after 4 months (Table 5).

Table 5. Mean moisture content(%) of pistachio powder samples during storage period.

Treatment	First day	First month	Second month	Third month	Fourth month
AN	2.10 ± 0.10^{a}	2.20 ± 0.17^{bc}	2.53 ± 0.77^{abc}	2.56 ± 0.20^{abc}	2.83 ± 0.11^{c}
AV	2.10 ± 0.10^{a}	2.36 ± 0.05^{abc}	2.36 ± 0.05^{abc}	2.70 ± 0.60^{bc}	2.76 ± 0.05^{bc}
FN	2.10 ± 0.10^{a}	2.30 ± 0.10^{abc}	2.53 ± 0.05^{abc}	2.56 ± 0.11^{abc}	2.80 ± 0.20^{c}
FV	2.10 ± 0.10^{a}	2.46 ± 0.45^{abc}	2.53 ± 0.35^{abc}	2.63 ± 0.15^{abc}	2.83 ± 0.11^{c}

* There are no significant differences between the means of treatments with common acronyms (compared with SPSS software at 5% level)
AN, Pistachio powder packed in cans in non-vacuumed conditions and stored in ambient Temperature ; AV, Pistachio powder packed in vacuumed cans and stored in ambient Temperature; FN, Pistachio powder packed in cans in non-vacuumed conditions and stored in freezed Temperature; FV, powder pistachios packed in vacuumed cans and stored in freezed Temperature.

Color

L^* index was not significantly different in pistachio powder samples during the storage period ($p>0.05$). Only a small difference between the control and other samples was observed during the storage period. As a result, the packaging atmosphere and temperature did not affect the L^* index. No factor of temperature and packing conditions during the studied time period affected a^* in pistachio powder samples. The factor b^* at probability level of 5% had no significant effect in different treatments of pistachio powder stored in different conditions. Although in the long run, this index is affected by time, weather and temperature, there was

no significant difference in b^* during the studied period. The mean L^*, a^*, b^* factors of samples are compared in Table 6.

Table 6. Mean L^*, a^*, b^* in pistachio powder samples during storage

Treatment		First day	First month	Second month	Third month	Fourth month
AN	L*	51.28±0.79^{a}	55.67±1.40^{b}	55.75±0.22^{b}	56.30±0.95^{b}	55.88±1.41^{b}
	a*	-3.92±0.43^{a}	-4.34±0.26^{a}	-4.10±0.68^{a}	-4.10±0.58^{a}	-3.83±0.25^{a}
	b*	23.17±2.09^{abc}	23.40±0.91^{abc}	22.86±0.48^{abc}	22.35±0.40^{a}	23.01±0.54^{abc}
AV	L*	51.28±0.79^{a}	55.95±2.03^{b}	56.96±0.47^{b}	55.67±0.36^{b}	56.66±0.87^{b}
	a*	-3.92±0.43^{a}	-4.16±0.17^{a}	-4.24±0.28^{a}	-4.21±0.49^{a}	-3.87±0.06^{a}
	b*	23.17±2.09^{abc}	23.11±0.75^{abc}	23.81±0.49^{abc}	22.67±0.78^{ab}	23.57±0.30^{abc}
FN	L*	51.28±0.79^{a}	56.81±0.88^{b}	56.33±0.57^{b}	56.96±0.46^{b}	56.43±0.60^{b}
	a*	-3.92±0.43^{a}	-4.34±0.31^{a}	-4.24±0.36^{a}	-4.59±0.39^{a}	-3.98±0.85^{a}
	b*	23.17±2.09^{abc}	24.25±1.26^{c}	23.72±0.41^{abc}	23.92±0.51^{bc}	23.79±0.73^{abc}
FV	L*	51.28±0.79^{a}	56.51±1.15^{b}	56.85±0.81^{b}	55.27±0.70^{b}	57.16±0.77^{b}
	a*	-3.92±0.43^{a}	-3.92±0.17^{a}	-4.29±0.16^{a}	-4.36±0.12^{a}	-3.90±0.17^{a}
	b*	23.17±2.09^{abc}	23.37±0.16^{abc}	23.65±0.31^{abc}	23.28±0.44^{abc}	23.22±0.11^{abc}

* There are no significant differences between the means of treatments with common acronyms (compared with SPSS software at 5% level)
AN, Pistachio powder packed in cans in non-vacuumed conditions and stored in ambient Temperature; AV, Pistachio powder packed in vacuumed cans and stored in ambient Temperature; FN, Pistachio powder packed in cans in non-vacuumed conditions and stored in freezed Temperature; FV, powder pistachios packed in vacuumed cans and stored in freezed Temperature.

Sensory Evaluation

The results of odor evaluation of different samples of pistachio powder showed that there was a significant difference between the samples ($p< 0.05$). The odor scores of pistachio powders in first day, FV1 and FV2 (4.9) were same and higher than freezed non-vacuumed cans and those stored at ambient temperature (Fig. 1). The lowest odor score observed in AN4(2) and then AV4(3.2). This result may be attributed to higher oxidation rate in ambient temperature in comparision with freezing that led to production of aldehyde esters and other volatile compounds.

The results revealed that with increasing the storage temperature and time, the taste score decreases and differences in taste between the samples stored in freezing and ambient temperatures are significant ($p< 0.05$). Also, the results showed that the difference between the packing conditions and its effect on taste was significant ($p< 0.05$). The highest taste score found in S0 and FV1 (4.930) and the lowest score(2.13) was observed in AN4 treatment (Fig. 1).

The effect of time, packaging conditions and storage temperature on color of pistachio powders were not significantly different ($p>0.05$) during the storage period(data not shown). The sensory score of color was 4.73 for pistachio powder in first day and it did not change in vacuumed samples during storage period. A slight decrease just observed in color score of non-vacummed filled cans due to higher oxidation rate but when the oxygen content of the product drops so rapidly, it can not make a significant difference in color(Shayanfar *et al*., 2008).

The results revealed that packaging under vacuum and ambient temperature preserve the texture and granulation of pistachio powder better while freezing created lumps and reduced uniformity in the texture and granulation of the treatments. During storage the score of texture decreased which was higher in frozen

samples. In first day and sample of AV1 the texture was scored as 4.8 or very good. However, the texture acceptance of product during the storage period dropped to score of 2.46 and 2.60 in freezed non-vacummed (FN4) and vacummed (FV4) samples, respectively.

The overall acceptance of pistachio powders was reduced during storage period with the highest score(4.93) for S0 and FV1 and the lowest score (2.46) for AN4. Oxidation and rancidity are one of the most important causes in reducing of product acceptance. Fig. 1. shows the trend of odor, taste and texture evaluation in pistachio powder samples during the storage period.

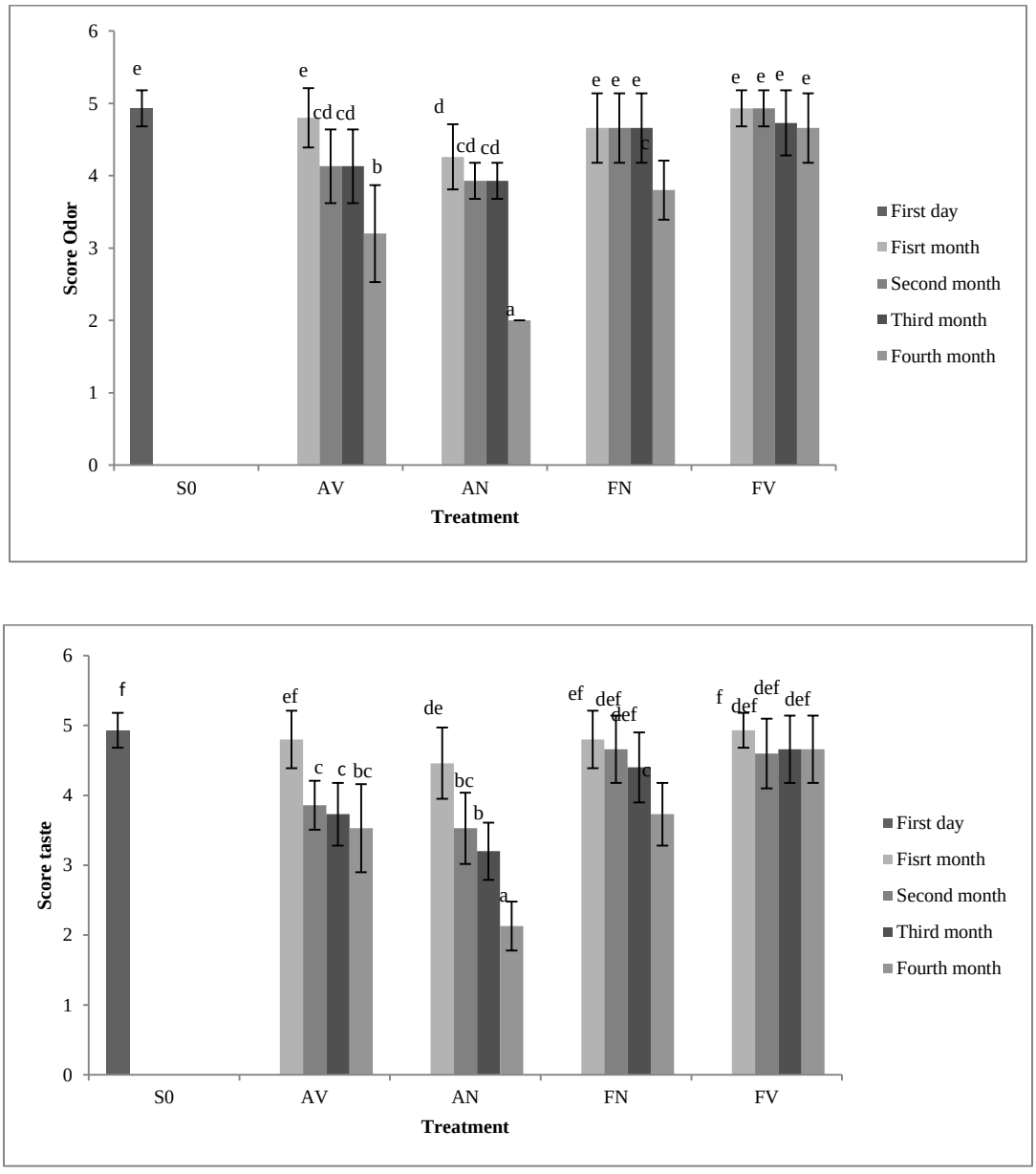

Fig.1. Sensory evalution (odor, taste, texture) of pistachio powder during the storage period.

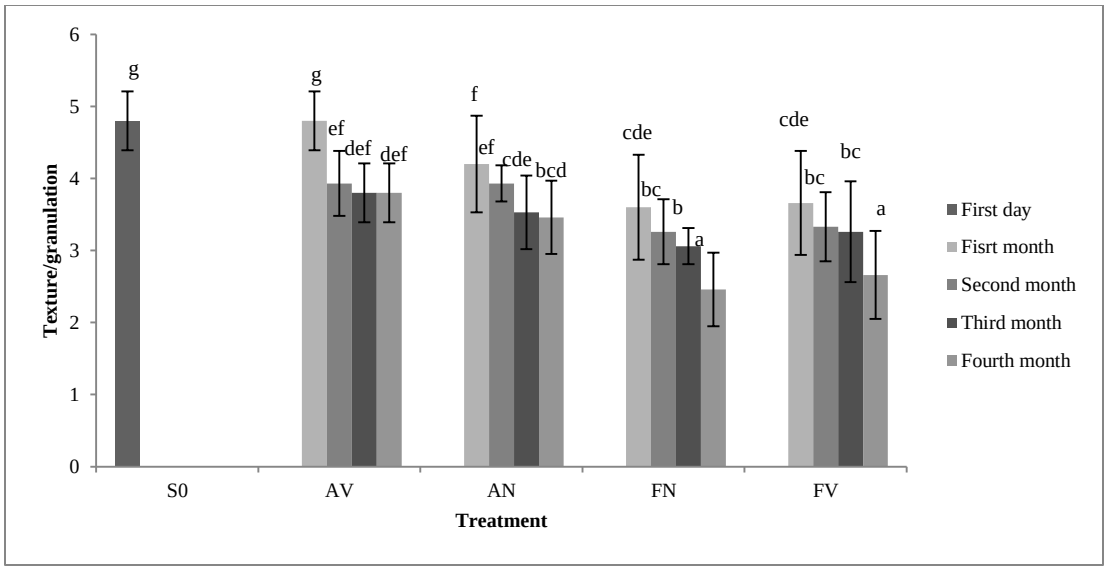

Fig.1. Continued.

S0, The control sample on first day immediately after grinding; AN, Pistachio powder packed in cans in non-vacuumed conditions and stored in ambient Temperature; AV, Pistachio powder packed in vacuumed cans and stored in ambient Temperature; FN, Pistachio powder packed in cans in non-vacuumed conditions and stored in freezed Temperature; FV, powder pistachios packed in vacuumed cans and stored in freezed Temperature.

Discussion

Free fatty acids increased with increasing storage time and temperature as well as oxygen content. Sedaghat (2010) also showed three factors of storage time, temperature and air, affected the content of FFA in pistachio. Lipase and esters causes oxidation reactions with catalase enzyme. These enzymes remove fatty acids from fat and release fatty acids, so free fatty acids can substrate oxidation reactions (Laskawy *et al*., 1983; Rai *et al*., 2007). On the other hand, temperature is an important factor influencing the activity of these enzymes and subsequently the content of free fatty acid, so that the activity of these enzymes is low at freezing temperatures and free fatty acids are released less. As a result, these enzymes are more active at higher temperatures leading to more fatty acids (Laskawy *et al*., 1983).

Acid Value was significantly higher in pistachio powder packed in air-filled cans and stored at ambient temperature than the other samples because the high temperatures and presence of oxygen increase the content of free fatty acids and subsequently AV. The AV also increased during the storage time . Similar report has been documented by Gamli and Hayoglu (2007). AV is increased due to increased hydrolysis of triglycerides in the pistachio due to the activity of lipase enzyme (Rai *et al*., 2007). Temperature is another factor affecting the AV. Sedaghat(2010) also reported that the AV of pistachios is increased with increasing storage temperatures and, consequently, increasing the oxygen content.

In non-vacuumed samples, the higher contact of sample with oxygen compared with the vacuum packed samples can lead to an increase in PV (Emami *et al*., 2011). As a result, freezing is also suggested as a factor inhibiting the increase in peroxide value, because high temperature and oxygen content are two important factors initiating and speeding up oxidation reactions

(Cai *et al*., 2013). The increase in PV of pistachio powders during storage can be attributed to the autocatalytic nature of lipid-oxidation reaction as oxidation products act as a catalyzer, thus increase the reaction rate with time (Fox and McSweeney, 1998). Oleic acid and linoleic acid are two main Unsaturated fatty acid in pistachios that the presence of these unsaturated compounds leads to their susceptibility to oxidation (Ghanei Zare *et al*., 2012).

The moisture contained in pistachio powder packed in cans depends on packaging type, the permeability of cans for oxygen, the moisture content of pistachios, and the ambient condition. Temperature, storage time and packing under vacuum or non-vacuum condition had no effect on the moisture content of pistachio powder and there was no significant difference ($p > 0.05$). This is mainly due to small range of changes in relative humidity in the storage area, and effectiveness of seal cans in controlling moisture content during storage (Epand,1998). On the other hand, pistachio have high levels of fat, proteins and peptides can react with lipids, and affect the resistance of the membrane and ultimately prevent water from coming out of the product (Epand,1998). Therefore, considering the insignificant difference in moisture content of samples, the oxidation trend cannot be due to changes in moisture content.

During storage time and in different samples no significant changes were observed in color parameters L^*,b^* and a^* coordinates among the treatments. Non-vacuume packaging and storage in ambient temperature did not contribute any changes on pistachio powder color. Light and moisture affect on color of product due to oxidation of pigments (Gamli and Hayoglu,2007) so it seems impenetribility of metal cans to light and low moisture content of pistachio powder were two important factors that preserved the color of samples .

Analysis revealed that the taste of all samples significantly ($p<0.05$) decreased during storage period. Sedaghat *et al*., (2006) reported that increasing temperature and oxygen concentration will increase the speed of oxidation reactions. Also, increasing the storage time will reduce the overall acceptance and taste score, which is due to increased oxidation of the product (Bakkalbası *et al*., 2012). As a result of the oxidation and corrosivity of pistachio oil fatty acids, carbonyl escape compounds, including aldehydes and ketones, are produced as secondary oxidation products. These compounds are the cause of unpleasant smell and taste in pistachio powder (Kamal-Eldin *et al*., 2003**).**

The effect of storage temperature, storage time and type of packaging on texture and granulation of the pistachio powder was significant ($p<0.05$) .Vacuum filling and freezing are two processes that may affect the morphology of the pistachio powder. This morphological change has an important influence on the flowability of the powders. The clumpy appearance in freezed powders might be attributed to their condenced moisture which led to adsorption of water to the surface. This surface water in pistachio powders may change the inter particle forces by changing the distance between the particles and finally, the vander Waals force, there by resulting in liquid bridge formation and decreased flowability(Majid *et al*.,2018). Sedaghat *et al*.(2006) found that temperature, storage time and type of packaging affected on texture of pistachio kernel.

Conclusions

In regards to economic value of pistachio powder, it is important to utilize techniques such as freezing and vacuum packing to increase its shelf-life during storage. Higher storage time, temperature, and oxygen content increased free fatty acids, peroxides value, and acid value, while there were no significant differences in color and moisture content. In terms of taste and odor, the score of pistachio powder samples reduced with increasing time, air content, and temperature, while the color of the samples did not change significantly according to assessors. This is while texture/granulation

scores were reduced by freezing and time. In addition, time reduced the overall acceptance in samples packed under normal air conditions. It was generally found that packaging under vacuum and then freezing, could increase the shelf life of pistachio powder.

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References

Abbey M, Noakes M, Belling GB, Nestel PJ (1994) Partial replacement of saturated fatty acids with almonds or walnuts lowers total plasma cholesterol and low density-Lipo protein cholesterol. AmericanJournal of Clinical Nutrition. 59, 995-999.

Alasalvar C, Shahidi F, Ohshima T (2003) Turkish Tombul hazelnut (*Corylus avellana* L.). Lipid Characteristics and oxidative stability. Journal of Agricalture and Food Chemistry. 51, 3797-3805.

AOAC (1990) Official methods of analysis. 14th edition. Association of Official Analytical Chemists, Washington, DC.

AOAC (2010) Official Methods of Analysis, 15th ed. Association of Official Analytical Chemists, Washington, DC.

Bakkalbaşı E, Yılmaz ÖM, Javidipour I, Artık N (2012) Effects of packaging materials, storage conditions and variety on oxidative stability of shelled walnuts. LWT-Food Science and Technology. 46(1), 203-209.

Cai L, Liu C, Ying T (2013) Changes in quality of low-moisture conditioned pine nut (*Pinus gerardiana*) under near freezing temperature storage. CyTA-Journal of Food. 11, 216-222.

Emami SH, Azadmard Demirchi S, Peyghambardoost H (2011) Study of some of the chemical properties of butter enriched with powdered nuts and hazelnut. Researches in Iran Science and Technology Industries. 7, 330-335.

Epand RM (1998) Lipid polymorghism and protein-lipid interactions. Biochimica et Biophysica Acta (BBA) .1376, 353-368.

Fox PF, McSweeney PLH (1998) Dairy chemistry and biochemistry. Blackie Academic & Profefssional. 67-145.

Gamlı ÖF, Hayoğlu İ (2007) The effect of the different packaging and storage conditions on the quality of pistachio nut paste. Journal of Food Engineering. 78(2), 443-448.

Ghanei Zare T, Tavakolipor H, Elhami Rad A (2013) Investigation on the effect of packing material and vacuum conditions on quality properties of raw pistachios dried during storage. Journal of food science and technology. 4(1), 65-71.

Hashemi N, Raei M, Sedaghat N (2007) Extraction of pistachio oil and examination of its qualitative properties under conditions of storage and packaging setting up. First National Conference on Pistachio Processing and Packaging. 314-325.

Hu FB, Stampfer MJ, Manson JE (1998) Frequent Nut Consumption and Risk of Coronary Heart Disease in Women: Prospective Cohort Study. British Medical Journal. 317, 1341-1345.

Kamal Eldin A, Velasco J, Dobarganes C (2003) Oxidation of mixtures of triolein and trilinolein at elevated temperatures. Lipid Science and Technology. 105, 165-170.

Laskawy G, Senser F, Grosch W (1983) Storage stability of roasted hazelnuts. CCB, Review for Chocolate, Confectionery and Bakery. 8, 21-23.

Majid I, Dar BN, Nanda V (2018) Rheological, thermal, micro structural and functional properties of freeze dried onion powders as affected by sprouting. Food Bioscience. 22,105-112.

Maskan M, Karataş Ş (1998) Fatty acid oxidation of pistachio of nuts stored under various atmospheric conditions and different temperatures. Journal of the Science of Food and Agriculture. 77, 334- 340.

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

Nikzadeh V, sedaghat N (2008) Investigating the effect of rooting on the quality and chemic composition of pistachio. Proceedings of the First National Conference on Pistachio Processing and Packaging. 379-388.

Raei M, Pour Azerang O, Hashemi N (2007) Evalution of the effects of closed and modified atmospheric conditions on properties physicochemical pistachios. Proccedings of the first national conference on pistachio processing and packaging, Ferdowsi University of Mashhad. 1-9.

Roozban MR, Mohamadi N, Vahdati K (2006) Fat content and fatty acid composition of four iranian pistachio (*pistacia vera* L.) varieties grown in iran. Acta Horticulturae (ISHS). 726, 573-578.

Sedaghat N (2010) Application of Arrhenius Kinetics to evaluate the stability of Pistachio nuts at various conditions. Middle-East Journal of Scientific Research. 6, 224-229.

Sedaghat N, Mortazavi A, Nasiri mahallati M (2004) Evalution of the quality of pistachio persistence by ransimet method. Agricultural Sciences and Technology. 18(1), 151-157.

Sedaghat N, Mortazavi A, Nasiri mahallati M (2006) Estimation of shelf-life of pistachios in different storage conditions. Agricultural Sciences and Natural Resources. 12(2), 127-134.

Sedaghat N, Tavakoli J (2011) Study of quality properties of Motika variety under different storage and packaging conditions. Iranian Journal of Food Science and Technology. 1, 17-26.

Shayanfar S, Kashaninejad M, Khomeiri M (2008) The effect of MAP and different atmospheric condition on the color of in Hull fresh pistachio nut. Mashhad, 18th National Congress on Food Technology. 1-6.

Wilkinson J (2005) Nut Grower's Guide: The Complete Handbook for Producers and Hobbyists. Landlinks Press. pp. 240. 175-188.

Wrolstad RE, Acree TE, EA Decker (2001) Current Protocols in Food Analytical Chemistry. New York: Wiley. pp. 1203. 371-580.