International Journal of Horticultural Science and Technology
Journal homepage: http://ijhst.ut.ac.ir

Effect of Sun-Drying and Roasting on Pistachio Quality and Health Benefits

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ARTICLE INFO

Article history:

Received: 22 April 2023,
Received in revised form: 18 September 2023,
Accepted: 30 September 2023

Article type:

Research paper

Keywords:

Antioxidant,
Fatty acids,
Malondialdehyde,
Minerals,
Processing

ABSTRACT

Since processing may affect the quality and benefits of foods, a study was conducted to compare some properties of fresh, sun-dried (constant water content of 4%) and oven-roasted (130 °C for 25 min) pistachio nuts of two cultivars. Carotenoid, iron, copper, manganese, total saturated, total unsaturated, palmitic, and linolenic fatty acids showed no statistical difference ($P \leq 0.05$) among the samples. Comparing the 'Akbari' cultivar, the 'Ahmadaghaei' cultivar had less anthocyanin and less palmitoleic acid. Drying and roasting reduced antioxidant activity, flavonoid content, and arachidonic acid while increasing kernel firmness, malondialdehyde, and hydrogen peroxide. Chlorophyll content was higher in dried and roasted than fresh status in both cultivars. Stearic acid had a stable content in 'Ahmadaghaei', but increased by drying and roasting in 'Akbari.' Oleic acid increased by drying and roasting in 'Ahmadaghaei.' In 'Akbari,' oleic acid first decreased by drying and then increased to the initial level by roasting. Linoleic acid decreased by drying and roasting in 'Ahmadaghaei'. In 'Akbari', it revealed an increasing trend by drying, but again decreased to the initial content after roasting. In conclusion, the conditions in this experiment for drying and roasting the pistachios were not harmful and had some advantages, leading to better pistachios storage.

Introduction

In recent years, clinical studies have revealed that increased consumption of nuts can improve human health. Pistachio seeds are the edible part of the *Pistacia vera* L. tree. They are a valuable part of the human diet in some regions of the world due to their high nutritional value, i.e., richness in unsaturated oils, vitamins, minerals, and bioactive compounds. Fresh pistachio is highly desirable for human health but perishable and unlikely to remain intact for more than a few days. Therefore, pistachios are routinely dried and then presented to the market by the producers (Sheikhi et al., 2019).

A common way of drying pistachios is traditional sun-drying, although other ways, such as oven or microwave, can also be applied (Kermani et al., 2017). However, some research indicates a partial

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loss of benefits after the drying process. In a pistachio cultivar 'Bianca,' sun-drying caused a reduction in total polyphenols, flavonoids, and α- and γ-tocopherols (Ballistreri et al., 2009). In another study, intermittent microwave drying had no substantial consequence on lipid and protein contents, while acidity and peroxide values were affected significantly (Kermani et al., 2017).

Dry pistachios may also be processed before marketing. One of the most common ways of processing pistachio seeds is roasting. Usually, some salt is added to pistachios before or during roasting as a seasoning and preservative. Chemical changes that occur in kernels during roasting lead to the distinct flavor, aroma, and color of roasted pistachio nuts despite lipid oxidation. These include changes in all plant substances affected by time-temperature treatments (Schlörmann et al., 2015). Roasting initiates lipid oxidation and the formation of carbonyl compounds. However, the antioxidant effect of products obtained from the Maillard reaction makes the seed oil more stable against oxidation during storage. Still, using high roasting temperatures reduces the quality of pistachio oil by increasing the peroxide index or thiobarbituric acid index (Nikzade and Sedaghat, 2009). Almost 90% of pistachio fatty acids are unsaturated. This amount of unsaturated fatty acid increases the nutritional value of this product but makes it susceptible to unwanted oxidation (Mohammadi et al., 2007; Abdolshahi et al., 2011).

Since the preservation of quality and nutritional value of pistachios is of great importance for human health, the current research aimed to compare several physical and chemical characteristics of fresh pistachios with sun-dried and oven-roasted pistachios. Since sun-drying and oven-roasting are two routine ways of drying and roasting pistachios, we applied these methods to achieve desirable results. The experiment was performed on two main pistachio cultivars, i.e., 'Akbari' and 'Ahmadaghaei.'

Materials and Methods

Plant materials

Ripe pistachio fruits of two main commercial cultivars, i.e., 'Akbari' and Ahmadaghaei,' were harvested from an orchard in Rafsanjan City, Iran, in September 2021. Both cultivars are high-quality and noble cultivars. In 'Akbari,' the width of the head and the bottom of the fruit is almost the same, and the color of the hull is deep pink to purple. But in the 'Ahmadaghaei' cultivar, the fruit is slightly sharper, and the skin color is pale pink to yellow. The sampling was done from four sides of at least 20 different trees. After transferring to the laboratory, the hulls were removed from the fruits, and the in-shell seeds (nuts) were grouped into three 0.5 kg parts. One part was used as fresh pistachios, and two others were dried in the sun until their moisture content reached a constant level of 4%. One part of the dried pistachios was soaked in 1% sodium chloride (NaCl) solution, placed in Pyrex Petri dishes (18 cm in diameter) as a single layer, and roasted in an electric oven (Memmert ULE500) at a temperature of 130 °C for 25 min. All the pistachios were stored at -80 °C until further use. There were four replications for each treatment group.

Firmness

After removing the shells, kernel firmness was measured using a tension-compression test machine (Santam company, Iran, model STM20). This device applies compressive force at a constant speed of 5 mm min^{-1} by a rod with a cylindrical tip of 8 mm diameter and 5 mm height, which is connected to the end of a dynamometer. Compression in each kernel was done at four points along two perpendicular diameters. The average of recorded values was reported in Newtons (N).

Photosynthetic pigments

Each sample (repeat) consisted of at least ten kernels. One g of each sample was ground in a small volume of 80% acetone (in water), and the mixture was centrifuged at 11000 g for 10 min. Extraction was repeated three times. The supernatants were collected and brought to 10 mL volume with 80% acetone. The absorbance was read at 470, 646.8, and 663.2 nm using a UV-visible spectrophotometer. The chlorophyll and carotenoid concentrations were calculated using the following formula and expressed as mg g-1 of fresh weight (Lichtenthaler, 1987).

$$Chl.a = (12.25\ A663.2) - (2.79\ A646.8)$$
$$Chl.b = (21.21\ A646.8) - (5.1\ A663.2)$$
$$Chl.T = Chl.a + Chl.b$$
$$Car = \frac{[(1000\ A470) - (1.8\ chl.a) - (85.02\ chl.b)]}{198}$$

Antioxidant activity

Antioxidant activity was determined by the 2,2-diphenyl-1- picryl-hydrazyl (DPPH) radical-scavenging method. Each sample (repeat) consisted of at least ten kernels. One g of each sample was ground in 80% methanol (in water), and the mixture was centrifuged at 11000 g for 10 min. Extraction was repeated three times. The supernatants were collected and brought to 10

mL volume with 80% methanol. Then, 900 µL of DPPH solution (500 µM) was added to 100 µL of plant extract. For the correction factor, 900 mL of distilled water was added to 100 µL of plant extract. A mixture of 100 µL of distilled water and 900 µL of DPPH solution was used as blank. The absorbance was read at 517 nm via a UV-visible spectrophotometer. The following formula calculated the inhibition percentage of the DPPH radical (Nazoori et al., 2021).

$$\text{Antioxidant activity (\%)} = 1 - \frac{\text{Sample absorbance} - \text{Correction factor}}{\text{Blank}} \times 100$$

Anthocyanin

Each sample (repeat) consisted of at least ten kernels. Of each sample, 0.1 g was completely ground in 10 mL of acidic methanol (pure methanol and pure hydrochloric acid at a volume ratio of 99:1); the juice was poured into a test tube with a screw head and placed in the dark at a temperature of 25 °C for 24 h. Then, it was centrifuged at 11000 g for 10 min, and the absorbance of the upper solution was measured at 550 nm. The concentration was calculated using the formula $A = \varepsilon bc$ and the extinction coefficient of 33000 $M^{-1}cm^{-1}$; and the results were presented in terms of micromoles per gram of fresh weight (A: absorbance, b: width of a cuvette, c: anthocyanin concentration, ε: extinction coefficient) (Wanger, 1979).

Flavonoid

An amount of 50 µL of methanolic extract (same as DPPH assay extract) was mixed with 10 µL of aluminum chloride (10%), 10 µL of potassium acetate (1M), and 280 µL of deionized water. The absorbance was read at 415 nm. Total flavonoid content was determined based on the standard quercetin curve and expressed as µg in 100 g of fresh weight (Nazoori et al., 2021).

Malondialdehyde

Each sample (repetition) consisted of at least 10 kernels. From each sample, 0.5 g was completely ground in 4 mL of 0.1% (v/w) trichloroacetic acid (TCA) solution and centrifuged at 11000 g for 5 min. One mL of the supernatant was mixed with 4 mL of 20% trichloroacetic acid containing 0.50% thiobarbituric acid and kept in a hot water bath for 30 min. Then, it was stored in cold water for 15 min and centrifuged at 11000 g for 5 min. The absorbance was read at 532 nm by a spectrophotometer. A standard curve was prepared by malondialdehyde, and the malondialdehyde content was obtained (nmol g^{-1} FW) (Nazoori et al., 2021).

Hydrogen peroxide

For H_2O_2 evaluation, 0.5 mL of trichloroacetic acid (TCA) extract (same as malondialdehyde assay extract) was mixed with 0.5 mL of potassium iodide (1 M) and 1 mL of potassium phosphate buffer (10 mM). The tubes were left in the dark at room temperature for 1 h. The absorption was read by a spectrophotometer at 390 nm. A standard curve was prepared by hydrogen peroxide and hydrogen peroxide content was obtained as µmol g^{-1} FW (Mandal et al., 2013).

Fatty acids

Each sample (repeat) consisted of at least 10 kernels. Of each sample, 0.2 g was completely ground in 1 mL of NaOH solution (0.5 N), poured into test tubes with a screw head, placed in a hot water bath (90 °C) for 10 min, and cooled at room temperature. One mL of boron trifluoride (BF3) 14% in methanol was added to each tube. The tubes were placed in a hot water bath (90 °C) for 10 min and cooled at room temperature. One mL of distilled water, 2 mL of hexane, and 2 ML of saturated NaCl solution were added to each tube. The tubes were vortexed for 1 min and then centrifuged at 11000 g for 5 min. The top layer was used for gas chromatography–mass spectrometry (GC-MS) analysis. One mL of each sample was injected into the device with a Hamilton syringe. An RTX- 2330- Restec-Canada (105 m * 250 µm * 0.2 µm) column was used. The run time was 20 min, with a specific temperature program (Table 1). Other parameters were as follows: Inlet (heater: 250 °C, pressure: 45.96 psi, septum purge flow: 2 mL min^{-1}, split: 100:1); detector (heater: 300 °C, H2 flow: 30 mL min^{-1}, air flow: 300 mL min^{-1}, N2 flow: 38.001 mL min^{-1}) (Park and Goins, 1994).

Table 1. Temperature program used in GC-MS.

Ramp	Temperature (°C)	Time (min)
-	140	1
20	180	9
20	200	7

Iron, copper and manganese content

The dry ash method was used to digest the samples. The steps involved homogenization, complete dehydration for 24-30 h at 105 °C, removal of lipids by ether for 12 h, weighing 2 g of dried samples in a porcelain pot, and placing them in an electric furnace at 550 °C for 6 h. The remaining white ash was dissolved in concentrated nitric acid, and each sample volume was brought to 10 mL with deionized water. The

analysis of the prepared samples was done by an atomic absorption device (AVANTA AA, GBC company). Calibration was done using standard solutions (Pelkin-Elmer, 1994; Devatkal, 2004).

Statistical analysis

The experiment design was a factorial based on a completely randomized design with four replications. Sources of variation were the hydration status of pistachio kernels (fresh, sun-dried, oven-roasted), pistachio cultivar ('Akbari' and 'Ahmadaghaei'), and their interaction. Mean values were calculated and reported as the mean value ± standard error of mean value. Data were analyzed using SAS 9.1 statistical software package, and Duncan's multiple range test (P≤0.05) was used for comparing mean values. Where the interaction of factors was significant, the data appeared in graphs. Where the simple effect of factors was significant, the data appeared in Tables only. The graphs were plotted in Microsoft Excel software.

Results

Firmness

Only the simple effect of hydration status was significant (P≤0.05) on seed firmness, while the interaction of hydration status and cultivar was not significant. Fresh and roasted pistachios had the lowest and highest firmness, respectively (Table 2).

Table 2. Effect of hydration status on some physical and chemical properties of pistachio seeds (P≤0.05).

Hydration status	Firmness (N)	Antioxidant activity (%)	Flavonoid (µg 100 g^{-1} FW)	Malondialdehyde (nanomol g^{-1} FW)	Hydrogen peroxide (µmol g^{-1} FW)	Arachidonic acid (%)
Fresh	15.35 ± 0.10^{c}	94.71 ± 0.10^{a}	5.36 ± 0.18^{a}	0.045 ± 0.002^{c}	1.63 ± 0.09^{b}	0.47 ± 0.01^{a}
Dried	21.03 ± 0.22^{b}	91.98 ± 0.15^{b}	3.65 ± 0.14^{b}	0.065 ± 0.004^{b}	2.57 ± 0.08^{a}	0.44 ± 0.01^{b}
Roasted	24.56 ± 0.19^{a}	91.15 ± 0.17^{b}	2.71 ± 0.15^{b}	0.089 ± 0.004^{a}	2.96 ± 0.04^{a}	0.42 ± 0.04^{b}

Total chlorophyll

Interactions between hydration status and cultivar were significant (P≤0.05) on total chlorophyll content of pistachio kernels. Pistachio kernels are rich in chlorophyll, hence their green color. The highest chlorophyll content was present in the 'Akbari' cultivar in dried state (0.23±0.01 mg g^{-1} FW) and in 'Ahmadaghaei' in roasted state (0.23±0.01 mg g^{-1} FW), while the lowest level occurred in fresh 'Akbari' pistachios (0.12±0.01 mg g^{-1} FW) (Fig. 1).

Total carotenoid

None of the simple and interactive effects were significant (P≤0.05) on the carotenoid content, which was between 0.0145 – 0.0827 mg g^{-1} FW, with no statistical difference among samples.

Antioxidant activity

The simple effect of hydration status was significant (P≤0.05) on antioxidant activity, while the interaction of hydration status and cultivar was not significant. The antioxidant activity of fresh kernels was higher than dried and roasted kernels, while there was no difference between dried and roasted kernels (Table 2).

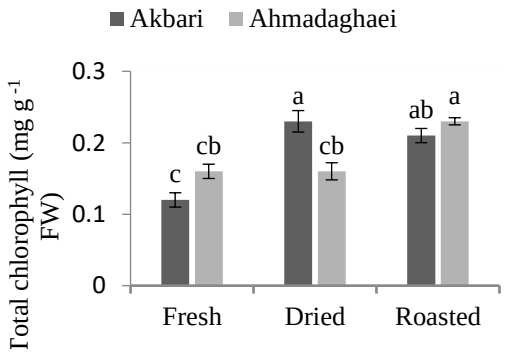

Fig. 1. Total chlorophyll content of kernels of two pistachio cultivars at fresh, sun-dried, and oven-roasted (P≤0.05).

Anthocyanin

The simple effect of cultivar was significant (P≤0.05) on anthocyanin content, but the interaction of hydration status and cultivar was not significant (Table 3).

Table 3. Effect of cultivar on some physical and chemical properties of pistachio seeds (P≤0.05).

Cultivar	Anthocyanin (μmol g^{-1} FW)	Palmitoleic (%)
Akbari	6.82 ± 1.14[a]	0.75 ± 0.01[a]
Ahmadaghaei	4.24 ± 1.12[b]	0.55 ± 0.01[b]

Flavonoid

The simple effect of hydration status was significant (P≤0.05) on flavonoid content, and the interaction of hydration status and cultivar was insignificant. Fresh kernels had a higher content of flavonoids (Table 2), revealing that sun-drying and roasting can decompose flavonoids.

Malondialdehyde

The simple effect of hydration status was significant (P≤0.05) on malondialdehyde content, and the interaction of hydration status and cultivar was insignificant. Fresh kernels showed the lowest, and roasted kernels had the highest malondialdehyde content (Table 2).

Hydrogen peroxide

The simple effect of hydration status was significant (P≤0.05) on hydrogen peroxide content, and the interaction of hydration status and cultivar was insignificant. Fresh kernels contained lower hydrogen peroxide than dried and roasted kernels (Table 2).

Fatty acids

As can be obtained from the results, unsaturated fatty acids are predominant in pistachio kernels. Oleic (50.16-58.33%, monounsaturated), linoleic (31.06-37.88%, polyunsaturated), and palmitic (7.45-9.09%, saturated) acids are the most abundant fatty acids in pistachio kernels.

None of the simple and interactive effects were significant (P≤0.05) on total saturated, total unsaturated, palmitic, and linolenic (polyunsaturated) fatty acids. These materials had a content between 8.77-10.72%, 88.35-90.92%, 7.45-9.09%, and 0.37-0.57%, respectively.

The interaction of hydration status and cultivar was significant (P≤0.05) on stearic (saturated), oleic, and linoleic acids (Fig. 2A, B, and C). Stearic acid had a stable content in the 'Ahmadaghaei' cultivar but increased by sun-drying and roasting in the 'Akbari' cultivar. Also, oleic acid content increased by drying and roasting the 'Ahmadaghaei' cultivar. However, in the 'Akbari' cultivar, oleic acid content first decreased by drying and then increased to the initial level by roasting. Linoleic acid decreased by drying and roasting in the 'Ahmadaghaei' cultivar. In the 'Akbari' cultivar, this fatty acid revealed an increasing trend by sun-drying but again decreased to the initial content after roasting.

For palmitoleic acid (monounsaturated), only the simple effect of cultivar (Table 3) and, for arachidonic acid (polyunsaturated), only the simple effect of hydration status (Table 2) was significant (P≤0.05). The 'Akbari' cultivar had more palmitoleic acid than the 'Ahmadaghaei.' Arachidonic acid content decreased by both sun-drying and roasting.

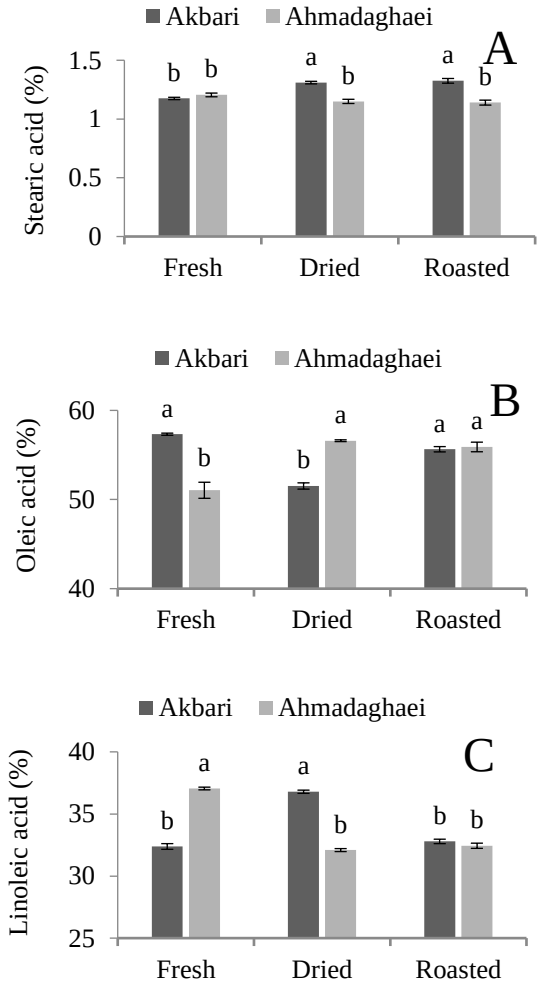

Fig. 2. Stearic (A), oleic (B), and linoleic (C) fatty acids in kernels of two pistachio cultivars at fresh, sun-dried, and oven-roasted states (P≤0.05).

Iron, copper and manganese content

None of the simple and interactive effects were significant ($P \leq 0.05$) on Fe, Cu, and Mn contents, reaching 73-97 mg kg^{-1}, 137-204 mg kg^{-1} and 7.5-21.5 mg kg^{-1} Fe, Cu, and Mn, respectively.

Discussion

Seed and fruit firmness is mostly related to the water content. As roasting causes more water loss than drying the seeds, the increase in firmness by roasting was acceptable. Chlorophyll is sensitive to heat, and its retention is dependent on temperature and duration of heat treatment (Roshanak et al., 2016). Sun-drying may not have generated enough heat to destroy the chlorophyll in kernels. Also, since the duration of roasting was relatively short, the amount of chlorophyll did not decrease. Therefore, the higher concentration of chlorophyll in dried and roasted kernels is due to the lower amount of water in them, which causes the amount of chlorophyll in dried and roasted kernels to be higher for the same weight as fresh seeds.

Besides their function as signaling agents, carotenoids act as natural defense compounds under stress conditions (Parween et al., 2014). Both sun-drying and roasting impose some heat stress on kernels and can lower carotenoid content. However, since the concentration of carotenoids in dried and roasted kernels is higher than in fresh seeds due to their smaller water content, this probably caused similarities in the carotenoid content of fresh, dried, and roasted kernels. So, if the heat did not destroy them, they might have had higher content in dried and roasted kernels than in fresh seeds.

This reduction in antioxidant activity, caused by sun-drying and roasting, can be mostly related to the deactivation of antioxidant enzymes due to heat and the destruction of some secondary metabolites that may stage antioxidant activity. Similarly, in another study, the phenolic content and the antioxidant activity in aqueous extracts of dry walnuts and pistachios were significantly (1.2 - 1.5 fold) lower than those of fresh walnuts and pistachios ($P<0.05$) (Arcan and Yemenicioglu, 2009). In hazelnuts and macadamia nuts, antioxidant capacity significantly decreased due to the roasting process (Schlörmann et al., 2015). Kernels of the Ahmadaghaei cultivar are paler than in the Akbari, which is related to less anthocyanin content in the former cultivar. Most pistachio seed anthocyanin content is in its testa, not the green cotyledons. The testa is a dehydrated part, and its water content is low even in fresh kernels. Therefore, water loss caused by drying and roasting did not change the anthocyanin content of pistachio kernels. In addition, Kirca et al. (2006) reported that most anthocyanins were reasonably stable during heating at 70 - 80 °C, which confirms previous data reported by Rhim (2002) on the thermal stability of most anthocyanins between 70 and 90 °C.

According to World Healthiest Foods (Mateljan, 2015), up to 80% of flavonoids can disappear in cooking. Zhang et al. (2019) stated that sunlight exposure can influence flavonoid metabolism, which results in a decreased flavonoid content. Moreover, most flavonoids are heat sensitive, and heating at 75 °C can directly deactivate enzyme activity and block the synthesis pathway of flavonoids (Zhang et al., 2019).

Nuts are good sources of polyunsaturated fatty acids. Malondialdehyde is a three-carbon dialdehyde produced from the decomposition of hydroperoxides, which are derived from the oxidation of polyunsaturated fatty acids and can form adducts with proteins and DNA. Its formation depends on the temperature and the duration of roasting. It correlates with polyunsaturated fatty acid levels in nuts. In a study conducted by Schlörmann et al. (2015), malondialdehyde of pistachios significantly increased (2.5 fold) after roasting (very similar to our results). This increase was even higher for walnuts (17 fold), while it was relatively moderate for hazelnuts (1.8 fold) and macadamia nuts (1.7 fold).

Hydrogen peroxide content estimates how much of an oil sample has undergone primary oxidation. Roasting increased the hydrogen peroxide content of kernels, probably due to increased cell destruction and deactivation of antioxidant enzymes (Hosseini Bai et al., 2017). Similarly, another study showed that hydrogen peroxide in pistachios of 'Kaleghoochi' and 'Akbari' increased upon drying, and this increase was even higher by temperature elevation from 80 to 100 °C (Nazari et al., 2016). Similar results were found in three other cultivars of pistachio (Kermani et al., 2017).

Unsaturated fatty acids are predominant in pistachio kernels. Oleic (monounsaturated), linoleic (polyunsaturated), and palmitic (saturated) acids were the most abundant fatty acids in pistachio kernels. This result agrees with previous research (Mohammadi et al., 2007; Abdolshahi et al., 2011). The simple and interactive effects were not significant on total saturated, total unsaturated, palmitic, and linolenic (polyunsaturated) fatty acid contents. The fatty acid composition of each oil can be considered an indicator of its physical properties, stability, and nutritional value. Although heat

causes some fatty acids to change to each other, total unsaturated and total saturated fatty acid content do not change due to the roasting of many kernels and fruits such as sesame (Ji et al., 2019), hazelnut (Alasalvar et al., 2010), olive (Blasi et al., 2018), and walnut (Jelokhani Niaraki and Ahmadi Kamazani, 2022). According to our results, this was also true for pistachio kernels.

As revealed from the results, the interaction of hydration status and cultivar was significant on stearic (saturated), oleic, and linoleic acids. Stearic acid had a stable content in the 'Ahmadaghaei' cultivar but increased by sun-drying and roasting in the 'Akbari' cultivar. This finding results from the fact that the roasting process would allow oxygen to react readily with unsaturated fatty acids and convert them to saturated fatty acids (Öz et al., 2021). Oleic acid content increased by drying and roasting in the 'Ahmadaghaei' cultivar. After drying or roasting, some polyunsaturated fatty acids transformed into oleic acid, a monounsaturated type. In the Akbari cultivar, oleic acid content first decreased by drying and then increased to the initial level by roasting. Linoleic acid decreased by drying and roasting in the Ahmadaghaei cultivar due to its polyunsaturation nature. Unsaturated fatty acids are oxidatively unstable at high temperatures, changing into some saturated fatty acids due to oxidation (Kırbaşlar et al., 2012). In the 'Akbari' cultivar, this fatty acid revealed an increasing trend by sun-drying but again decreased to the initial content after roasting.

The cultivar simple effect was significant on palmitoleic acid (monounsaturated). The fatty acid composition of pistachio oil may vary slightly between different cultivars. Similar to our results, in another study, the 'Akbari' cultivar had more palmitoleic acid than the 'Ahmadaghaei' cultivar (Dini et al., 2016). Arachidonic acid was the only fatty acid affected by the hydration status of kernels. It decreased by sun-drying and roasting due to its polyunsaturation nature and the relatively high number of double bonds, and four double bonds are present in arachidonic acid. Polyunsaturated fatty acids are more sensitive to oxidation as imposed by heat and dehydration (Nikzade and Sedaghat, 2009).

Fe, Cu, and Mn contents did not change by drying and roasting. Pistachio kernels are a rich source of many minerals. The importance of these mineral elements in human health has already proved essential. They are implicated in several bodily functions, such as energy production and multiple biological reactions (Steinberg et al., 2003). Some research showed that the mineral contents of different nuts may alter after drying or roasting through various methods. These changes may result from mineral loss in water through diffusion during processing. The increase in mineral content after processing may be due to the antinutritional material present in the nuts, which were complex to the mineral. When heat destroys these significantly, it leads to an increase in mineral concentration (Tonfack Djikeng et al., 2018). It seems that the processing condition in our study was not so strong to affect mineral content.

Conclusion

The objective of this study was to investigate the possible effects of sun-drying and oven-roasting on some physical and chemical properties of pistachio seeds from two pistachio cultivars. Some essential characteristics of the kernels, several vital elements such as iron, copper, manganese, and the total amount of saturated and unsaturated fatty acids, did not change compared to fresh pistachios. Drying and roasting had advantages, such as increasing chlorophyll and oleic acid. Dried and roasted kernels were also firmer than fresh ones. Although DPPH scavenging capacity and flavonoids decreased malondialdehyde and hydrogen peroxide, they increased slightly after drying and roasting. We conclude that the conditions used for drying and roasting pistachios in this research were not harmful and had advantages that led to better conditions for pistachio storage.

Author contributions

FN planned the experiment. EZ prepared the manuscript. HR did the lab experiments.

Funding

This research was funded by Vali-e-Asr university of Rafsanjan.

Conflict of Interest

The authors indicate no conflict of interest in this work.

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