Investigating the packaging effect on the quality of fresh pistachio fruit during storage

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Abstract

Background: Pistachio (*Pistacia vera* L.) belongs to the Anacardiaceae family. It has many phenolic compounds and has recently become one of the 50 food products that have high antioxidant potential.

Materials and methods: The popularity of fresh pistachios has been growing in recent years due to demand based on health benefits. Biochemical and physiological indexes of fresh pistachios changes after harvest, and consequently, it has a short shelf life.

Results: Overall, the packaging application can be considered an alternative approach for maintaining the fatty acid composition, respiration rate, antioxidant activity, total phenolic content, and sensory flavor of harvested fresh pistachio fruit.

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1. Introduction

The genus Pistacia belongs to the Anacardiaceae family. In all species of this genus are pollinated by wind and dioecious. The pistachio (Pistacia vera L.) is the only important domestic and commercial species in the genus Pistacia. Other species are mostly used as a base and in limited cases for oil extraction, food supply for domestic animals or fruit consumption in rural areas of different countries [1]. Genetic characteristics of rootstock and scion, unbalanced nutrition, climatic conditions and irrigation, and insuitable harvest time are responsible for producing early-split and cracked nuts. The most important physiological conditions affecting the quality and the yield of pistachio crops are early-split nuts, blankness and cracking[2]. The quality of a split pistachio nut is defined by its size and shape, moisture content, and biochemical compositions (e.g., carbohydrate, fat, and protein). Determining the date of harvest of pistachio nuts is one of the most important gardening methods that increases its quality. Any change in harvest time (early and late) decrease the pistachio quality. Early harvested nuts are mostly immature and non-split, often including an unripe kernel. Delay in pistachio harvest, resulted to vulnerable of pistachio to hull cracking, hull and kernel decay, shell staining, mechanical injuries, fruit shedding, insects, and bird attacks. Contamination of kernel by Aspergillus fungus, is one of the result of late harvesting [2]. Although biochemical compositions, e.g., carbohydrate, fat, and protein, are less attended by the growers, they affect the real taste of pistachio nuts, ensuring their nutritional and health value. According to Labavitch et al. [1982], the maximum carbohydrate, fat, and And there is protein at the optimal harvest time when the hull is fully mature [3]. Thus, Improper harvesting performance severely affects the composition characteristics of nuts and decreases its quality [2]. Total pistachio production in the world reached about 1 057 566.00 tons in 2016. The USA is one of the main producers with more than 406 646.00 tons, representing approximately 38.45% of pistachio production. Iran, Turkey, Syria, and Greece are the other leading pistachio producers. [4]. It is broadly known as green gold because of its economic and nutritional values [5]. The kernels are a main source of oil (50- 60%) and contain oleic and linoleic fatty acids, essential for the human diet [6]. Pistachio is a nourishing snack; however, its fresh consumption is limited to the harvest season. Despite the high nutritional value of fresh pistachio, business people and farmers are often unwilling to keep or export it because of fruit decay. Fresh pistachios, which are considered as a fresh crop, rot rapidly and have a short shelf life due to physiological damage and mechanical damage about 35-40 days after harvest. One of the main factors reducing the quality of pistachios is enzymatic browning. This phenomenon usually damages the sensory value of products because it changes color, taste and softness. The enzyme polyphenol oxidase (PPO) will cause enzymatic oxidation of phenolic compounds and pistachio browning [6]. According to scientific studies, pistachio nuts are a rich source of vitamins (α-tocopherol, γ-tocopherol), minerals, and bioactive compounds, including lutein, anthocyanins, and especially avonoids. Interestingly, the information connected to this nut shows that various environmental and genetic factors such as type of cultivar, cultivating, roasting, and processing can critically affect the ultimate content of bioactive compounds in pistachio [7]. Earlier studies have

reported that sun-drying leads to 60% and 38% loss in anthocyanins and vitamin E, respectively. Furthermore, flavonoids, phenolics, and stilbenes are significantly reduced during sun drying [8]. In recent years, fresh pistachio has become more important than dried one because of its better taste, as well as the dried pistachio's lower nutritional value due to processing and higher added value [9]. Recently published reports suggest that reactive oxygen species (ROS) are the most pertinent agents to disrupt intracellular membrane for inducing oxidization in this part of plant tissues [10]. Most importantly, scientific data indicate that antioxidants are effective hurdles against ROS molecules by detoxification of these dangerous agents through scavenging their potential to interact with cellular targets. Therefore, preventing the overactivity of oxidant systems and related enzymes prevents the phenomenon of browning after harvesting fresh fruit [7]. The popularity of fresh pistachios has been growing in recent years due to demand based on health benefits and grower returns [8]. Therefore, the development of modified-atmosphere packaging (MAP) and controlled-atmosphere storage would extend the postharvest life and maintain quality. Reducing the loss of nutritive constituents of fresh in-hull or hulled pistachio nuts would be a great advantage for the fresh pistachio industry [8]. Using antioxidant compounds and packaging is recommended to maintain the quality of fresh pistachio since it slows down respiration and metabolic activities and retards microbial growth [6]. Raei et al. [2010] studied the five-layer compound film, modified polypropylene, and metalized plastic, on the storage of roasted pistachio nuts [11]. Results showed that the best quality and long shelf-life of pistachio nuts was obtained in metalized and five-layer films with gases N2/CO2 and vacuum conditions better kept. Raei and Jafari [2011] studied the effect of four packaging materials (cellophane, two-layer plastic pouch, three-layer plastic pouch, and metal can) on quality attributes of pistachio nuts stored in two temperatures (ambient and 40°C) for one year. Results indicated that two- and three-layer [12] polymer pouches resulted in higher quality attributes for the stored pistachios. Shaker Ardekani and Karim [2012] showed that the aflatoxin contents and moisture of whole pistachio was impacted by type of film, during storage According to previous studies, after storage, the respiration rate, hull color, strange flavor, and odor of the fruits stored in the packages were higher than those of the control treatment. The higher DPPH scavenging activity was found [13] in package-treated fruit during storage and displayed significantly higher phenolic content than other treatments. The current study aims to investigate the packaging to maintain the quality of fresh pistachio fruit.

2. Materials and methods

2.1. Materials

In this study, varieties of fresh raw pistachios (Pistacia vera L.) were used for the experiments. These pistachios were provided by the local commercial suppliers from a commercial orchard in Rafsanjan-Kerman in Iran and Antep examples from Gaziantep in Turkey at the beginning of the harvest season on 30 September 2019.

2.2. Methods

2.2.1. Sensory profile analysis

Sensorial properties of the fresh stachio samples were tested by eight semi-trained panelists using hedonic sensory analysis form with a rating scale of 1-9 points, where 1 and 9

expressed the lowest and the highest acceptability, respectively [14, 15].

2.2.2. Total phenolics

The concentration of phenolic compounds in the extracts was determined according to the Folin–Ciocalteu method [16]. The samples (0.2 ml) were mixed with 1.0 ml of 10-fold-diluted Folin–Ciocalteu reagent and 0.8 ml of 7.5% sodium carbonate solution; once the mixture was kept for 30 min at room temperature, the absorbance was measured at 765 nm using UNICAM 8620 UV–Vis spectrophotometer. Phenolic compounds in the extracts were estimated in triplicate, and results were reported on average.

2.2.3. Antioxidant activity assay

1 g of fresh fruit hull was entirely homogenized in 9 mL of 80% (v/v) methanol using Ultra-turrax for 3 min at 4 °C. The prepared extract was easily centrifuged at 10,000 × g for 10 min to remove any undesirable impurities. The pure extract was stored in the freezer at -20 °C for further analysis. Antioxidant activity (DPPH scavenging activity) was measured based on the capacity of the extract to sequester the DPPH (2, 2- diphenyl-1-picrylhydrazyl) radical, according to the approach previously suggested by Sidewell et al. (2002) [17].

AA% = [(Abs blank – Abs sample)/Abs blank] × 100}

2.2.4. Fatty acid composition

The fatty acid composition of the samples was determined according to Yalcin et al. [2011]. The oil (100 mg) was saponified with 100 mL of 2 mol/L KOH., and 3 mL hexane was added to the mixture. The results were expressed as g of fatty acid/100 g total fatty acids (%) [18,19].

2.2.5. Respiration rate

The headspace gas composition (percentage O2 and CO2) of passive-MAP treatments was determined in each storage period, immediately after removal from cold storage and before opening the packages using a portable CO2/oxygen analyzer (Mode l900141; Bridge Analyzers, Inc., 5198 Richmond Road, Bedford Heights, Ohio 44146, USA) with electrochemical and non-dispersive infrared sensors for O2 and CO2, respectively. To determine the post-storage ethylene production and respiration rate, all packages at each storage period were removed from the cold storage, opened, and exposed to ambient laboratory conditions for two h. A 150 g sample of pistachios was collected from each package and placed in the 2 L airtight respiration jars at 20 ∘C, being allowed to equilibrate for two h. Gas samples for ethylene measurement were taken from the outlet tubes of the jars using 10 mL plastic syringes and injected into a gas chromatograph (Series 400, AGC; Carle Instruments Co., Anaheim, CA, USA) equipped with a flame ionization detector. The gas chromatograph uses two columns, 1.22 m and 0.305 m, 8% sodium chloride on alumina F-1 80/100 (Chandler Engineering–Carle Chromatography, Tulsa, OK, USA). The gas chromatograph's injector, detector, and oven temperatures were set at 80 ∘C, and the carrier gas was nitrogen at a flow rate of 0.42 mL s−1. Ethylene production was expressed as nanoliters per kilogram per hour. Gas samples for respiration rate were taken from the same jars following the same procedure, but 1 h earlier than the ethylene samples, and then were injected into an infrared gas analyzer (model

PIR-2000R; Horiba Instruments Co., Irvine, CA, USA). The respiration rate was expressed as milliliters of CO2 per kilogram per hour [20 ,21].

3. Statistical analysis

Dtat analysis were evaluated by ANOVA and Duncan Multiple Test ($p < 0.05$). Cluster Analysis and Principal Component Analysis (PCA) were performed using the evaluation version of XLSTAT 2007 (Addinsoft) to determine the relationship among pistachio nuts by considering common volatiles and flavor characters.

4. Results and discussion

4.1. Sensory characteristics

The result considered taste, odor, and strange flavor, decreased during storage. Storage period and packaging type had a significant ($p<0.05$) effect on all sensory attributes except for juiciness, assessed by the group of panelists. Shayanfar et al. [2011] obtained similar results by pointing out that the MAP condition positively affects the sensory quality of fresh pistachio samples [19].

Table 1 Sensory analysis results of fresh raw pistachio samples in different packaging systems during storage

Sensory properties		Storage time (day)			
	Sample	**First**	**10**	**20**	**30**
Hull color	CP	$8.4^{Aa}\pm 0.7$	$7.4^{ABa}\pm 0.5$	$7.1^{Ba}\pm 1.4$	$7.4^{ABab}\pm 0.7$
	MAP	$8.4^{Aa}\pm 0.7$	$5.0^{Bc}\pm 1.2$	$5.4^{Bb}\pm 1.1$	$8.0^{Aa}\pm 0.9$
	VP	$8.4^{Aa}\pm 0.7$	$6.2^{Bb}\pm 0.7$	$5.4^{Bb}\pm 1.2$	$6.4^{Bb}\pm 1.1$
Pistachio color	CP	$8.5^{Aa}\pm 0.8$	$8.0^{ABa}\pm 0.8$	$6.6^{Ba}\pm 2.1$	$7.9^{ABa}\pm 1.0$
	MAP	$8.5^{Aa}\pm 0.8$	$7.0^{Bab}\pm 0.9$	$7.1^{Ba}\pm 0.8$	$7.9^{ABa}\pm 0.8$
	VP	$8.5^{Aa}\pm 0.8$	$6.7^{Bb}\pm 1.0$	$6.8^{Ba}\pm 1.6$	$7.0^{Ba}\pm 0.8$
Juiciness	CP	$7.5^{Aa}\pm 1.2$	$7.7^{Aa}\pm 0.7$	$6.3^{Aa}\pm 1.7$	$7.3^{Aa}\pm 1.6$
	MAP	$7.5^{Aa}\pm 1.2$	$7.0^{Aa}\pm 1.1$	$7.4^{Aa}\pm 0.7$	$7.1^{Aa}\pm 1.5$
	VP	$7.5^{Aa}\pm 1.2$	$7.0^{Aa}\pm 0.8$	$6.6^{Aa}\pm 1.7$	$6.3^{Aa}\pm 1.3$
Taste	CP	$8.3^{Aa}\pm 0.7$	$7.7^{Aa}\pm 1.0$	$7.1^{Aa}\pm 1.5$	$7.8^{Aa}\pm 1.0$
	MAP	$8.3^{Aa}\pm 0.7$	$6.9^{ABa}\pm 1.0$	$6.0^{Ba}\pm 1.3$	$7.6^{Aa}\pm 1.4$
	VP	$8.3^{Aa}\pm 0.7$	$7.1^{ABa}\pm 0.6$	$6.6^{ABa}\pm 1.9$	$6.0^{Bb}\pm 1.3$
Odor	CP	$8.1^{Aa}\pm 0.8$	$8.0^{Aa}\pm 0.8$	$7.5^{Ab}\pm 1.3$	$8.0^{Ab}\pm 0.8$
	MAP	$8.1^{Aa}\pm 0.8$	$6.4^{Bb}\pm 1.4$	$5.9^{Bb}\pm 1.2$	$8.0^{Ab}\pm 0.9$
	VP	$8.1^{Aa}\pm 0.8$	$6.4^{Bb}\pm 1.3$	$6.1^{Bb}\pm 1.6$	$6.4^{Bb}\pm 1.1$
Strange flavor and odor	CP	$8.8^{Aa}\pm 0.5$	$8.1^{ABa}\pm 0.8$	$7.0^{Ba}\pm 1.8$	$8.0^{ABab}\pm 0.8$
	MAP	$8.8^{Aa}\pm 0.5$	$7.1^{BCa}\pm 1.2$	$6.5^{Ca}\pm 1.3$	$8.1^{ABa}\pm 1.4$
	VP	$8.8^{Aa}\pm 0.5$	$7.1^{ABa}\pm 1.1$	$6.0^{Ba}\pm 1.9$	$6.4^{Bb}\pm 1.8$
Overall visual and flavor acceptance	CP	$8.5^{Aa}\pm 0.5$	$7.9^{ABa}\pm 0.8$	$7.4^{Ba}\pm 1.1$	$7.9^{ABa}\pm 0.6$
	MAP	$8.5^{Aa}\pm 0.5$	$6.3^{Bb}\pm 1.0$	$5.9^{Ba}\pm 1.1$	$7.8^{Aa}\pm 1.0$
	VP	$8.5^{Aa}\pm 0.5$	$6.6^{Bb}\pm 1.1$	$6.6^{Ba}\pm 1.5$	$6.1^{Bb}\pm 1.0$

CP: conventional packaging, MAP: modified atmosphere packaging, VP: vacuum packaging.

^{aec}: Values in the column with different lowercase letters were significantly different at $P < 0.05$.

Analysis was carried out in triplicate.

Table 2 shows the sensory scores of fresh dehulled pistachio fruits stored under passive-MAP and ambient air (control) at 0±0.5∘C and 90±1% RH. After 105 days of storage, passive-MAP stored fruits scored significantly higher, about 2.83-, 1.76-, and 2.36-fold for overall acceptability, taste, and aroma, respectively, than control fruits ($P \leq 0.01$). Furthermore, fruits in the control treatment had significantly higher scores for off-flavor (2.87-fold) and off-odor (2.74-fold) compared with the passive-MAP treatment ($P \leq 0.01$). Passive-MAP successfully maintained the sensory quality of fresh pistachio fruits above the consumer acceptance limit of 3 out of a 5 score for overall acceptability, taste, and aroma and below the consumer acceptance limit of 2 out of a score of 5 for off-flavor and off-odor. However, fruits stored under the control treatment were not consumable at the end of 105 days of storage period [8].

Table 2 Sensory quality of dehulled fresh pistachios (*Pistacia vera* L. cv. Kerman) under passive-modified atmosphere packaging (passive-MAP) and ambient air (control), after 105 days of storage at 0 ± 0.5 °C and 90 ± 1% relative humidity

	Sensorial attribute				
Treatment	**Overall acceptability[a,b]**	**Taste**	**Aroma**	**Off-flavor**	**Off-odor**
Passive-MAP	**4.25 ± 0.12a**	**3.75 ± 0.1a**	**3.9 ± 0.19a**	**1.55 ± 0.05b**	**1.55 ± 0.05b**
Control	**1.5 ± 0.12b**	**2.12 ± 0.16b**	**1.65 ± 0.15b**	**4.45 ± 0.17a**	**4.25 ± 0.05a**

[a] A score of 0–5 was used, in which 5 represents the most liked attributes, and 0 represents the attributes most disliked for overall acceptability, taste, and aroma. For the off-flavor and off-odor, 5 and 0 represent the highest and the lowest intensity, respectively.

[b] Data are presented as means ± SE of four replicates. In the same column, means followed by the same letter are not significantly different according to the least significant difference ($P \leq 0.01$).

4.2.Total phenolics

The effects of sodium nitroprusside (SNP) on the TPC of fresh pistachio fruit are illustrated in Fig. 1. The results suggested that the TPC of hull tissues continuously decreased during storage time while fruit treated with SNP, especially 15μM SNP, significantly delayed the TPC decline during storage. Overall, fruit treated with 15 μM SNP displayed significantly higher phenolic content than other treatments over the storage period [7].

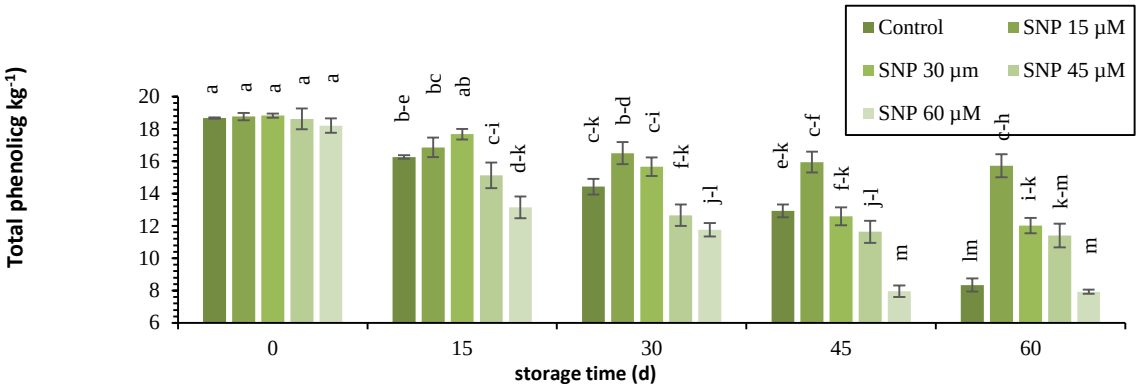

Fig. 1. Effect of SNP on total phenolics content of fresh pistachio hull; Vertical bars represent the S.E. Means (n =4) with the same letters on columns do not differ significantly.

4.3.Antioxidant activity

The observed changes in antioxidant capacity in fresh pistachio fruit during storage are depicted in Fig. 2. Also, the antioxidant capacity of SNP-treated fruit declined more slowly than control groups. The results also showed DPPH scavenging activity in treated fruit (15µM) to be higher compared with other treatments significantly ($P < 0.01$) [7].

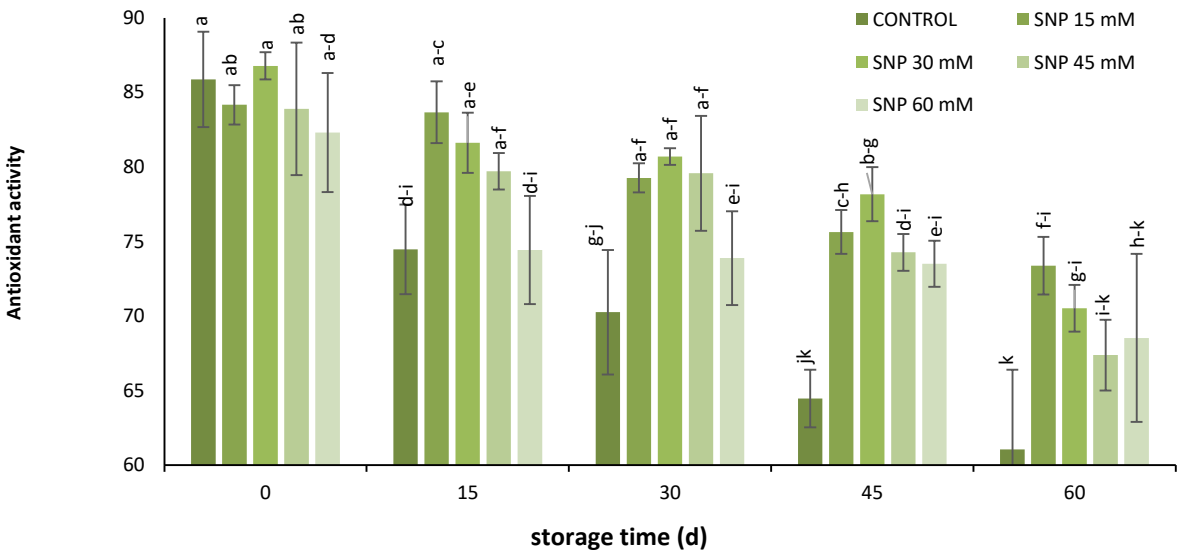

Fig. 2. Effect of SNP treatment on DPPH scavenging activity of fresh pistachio hull; Vertical bars with the same letters on columns do not differ significantly.

4.4. Respiration rate

The initial value of respiration rate of fresh pistachios was about ~ 40ng kg^{-1} s^{-1} at ambient temperature and nearly constant in all treatments. The respiration rate of pistachio decreased strongly harply until 30 days in cold storage, then increased toward the end of storage (Table 3). In this experiment, the SNP treatment at 15 and 30 µM had effectively reduced the respiration rate compared to control and other treatments [7].

Table 3 Effect of SNP treatment on the respiration rate of fresh pistachio fruits

	Storage time (d)	SNP Concentrations (M)				
		0	**15**	**30**	**45**	**60**
Respiration rate	0	31.6 ±1.4 $^{d-f}$	33± 1.9 $^{c-e}$	37.4 ± 0.4 $^{b-d}$	33.1 ± 0.6 $^{c-f}$	33.7 ±0.8 $^{c-f}$
	15	19.9 ±1.9 ^{i}	10.7 ± 1.0 ^{j}	12.4 ± 0.8 ^{j}	20.1 ± 0.5 ^{i}	29.7 ±0.5 $^{e-g}$
	30	20.2 ±2.5^{i}	10.9 ± 1.0 ^{j}	12.7 ± 1.0 ^{j}	20.2 ± 1.7 ^{i}	29.7 ±0.8 $^{e-g}$
	45	30.3 ±2.1 $^{e-g}$	24.9 ± 0.8 $^{g-i}$	19.9 ± 0.8 ^{i}	40.2 ± 1.7 ^{b}	40.0 ± 1.2 ^{bc}
	60	41.9 ±2.0 ^{b}	26.9 ± 1.2 $^{f-h}$	22.1 ± 1.4 ^{hi}	42.4 ± 2.5 ^{b}	56.4 ± 2.3 ^{a}

The mean ± S.E. Means (n = 4) with the same letters in rows do not differ significantly.

Fresh dehulled pistachios stored at 0◦C exhibited a gradual decrease in ethylene emission rate under passive-MAP and control conditions, with average values of 99.66nLkg−1 h−1, 36.59nLkg−1 h−1, and 19.97nLkg−1 h−1 over 0days, 30days, and 60days of storage, respectively (Fig.4(b)). Ethylene emission was reduced by 79.96% of the initial rate after 60days ($P \leq 0.01$). However, it was not detectable after 105days of storage at 0◦C. Passive-MAP had no significant effect on ethylene production rate compared with the control treatment (data not shown). Changes in respiration rates of fresh dehulled pistachios stored under passive-MAP and ambient air (control) for 105days at 0◦C are shown in Fig.4(a). The initial respiration rate was 36.09mL CO2 kg−1 h−1 at ambient temperature before cold storage. For the control treatment, the respiration rate slightly increased during 60days of storage; however, it decreased at the end of the storage period ($P \leq 0.01$). Conversely, respiration rates of fruits stored under passive-MAP increased rapidly throughout the storage, reaching a 5.85-fold increase over the initial value by the end of the study. After 105days of storage, the respiration rate of the fruits stored in the passive-MAP packages was 5.3-fold higher than those of the control treatment. Pistachios are non-climacteric: fruit ripens without ethylene and respiration bursts. Labavitch et al. [1982] reported ethylene production rates in pistachio fruits to be generally low (<0.06μLkg−1 h−1); respiration rates were in the ranged∼110–60mLCO2 kg−1 h−1 during 16 August–27 October. Toumadje et al. [1980] showed that ethylene production and respiration rates during fruit growth and development ranged from ∼0.2–0.44μLkg−1 h−1 and 36–125mL CO2 kg−1 h−1 respectively. According to their results, there was no indication of a climacteric peak in respiration and ethylene production in pistachio fruits [21].

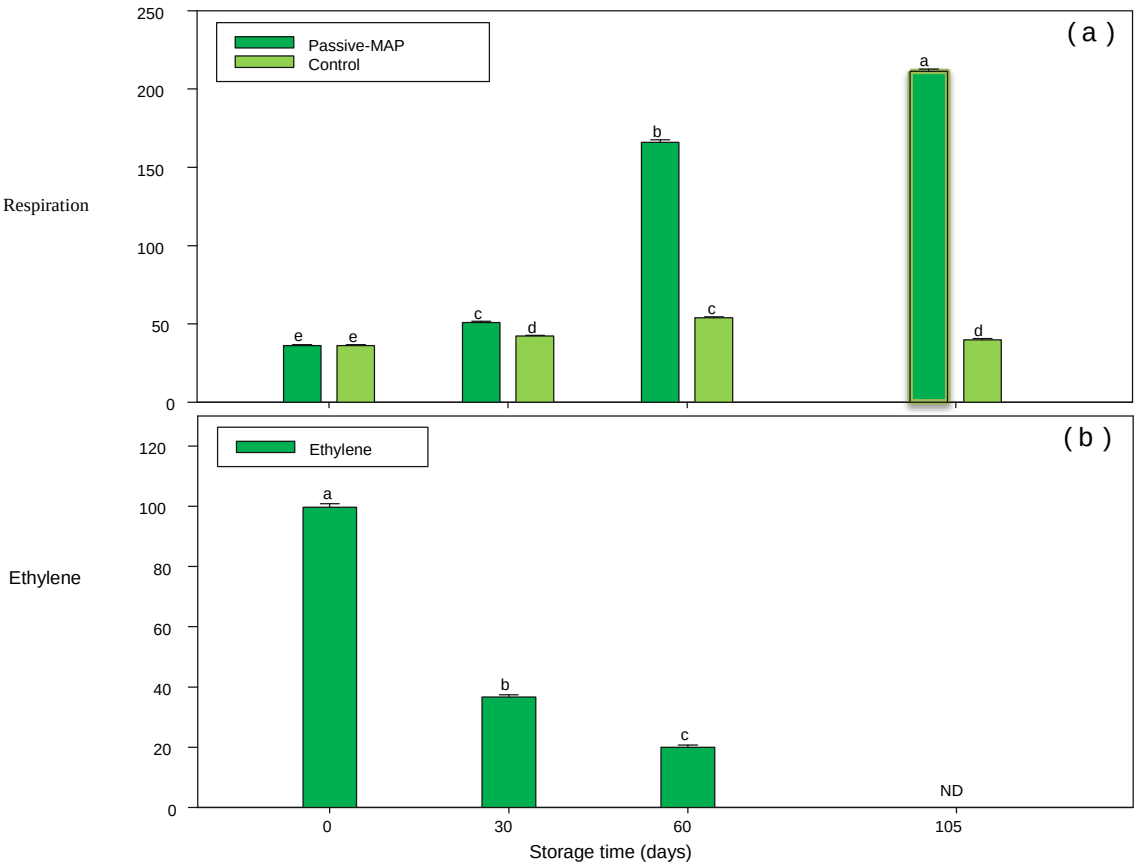

Fig. 3. (a) Respiration rate and (b) ethylene production of de-hulled fresh pistachios(*Pistacia vera* L.cv.Kerman), under passive-modified atmosphere packaging (passive-MAP) and ambient air (control), stored at 0 ± 0.5 °C and 90 ± 1% relative humidity. Means followed by at least one similar letter for each parameter are not significantly different according to the least significant difference ($P \leq 0.01$). Vertical bars indicate the standard errors of four replicates. ND: not detected.

4.5.Fatty acid composition

Pistachios are a great source of fatty acids essential for human nutrition containing saturated (SFA) (myristic, palmitic, stearic, arachidic, and behenic), monounsaturated (MUFA) (palmitoleic, oleic, and eicosenoic), and polyunsaturated (PUFA) (linolenic and linolenic) fatty acids. <11.6% of the total pistachios fatty acids are saturated. Pistachio oil is considered an oxidation-resistant oil due to its high content of oleic acid and low amounts of polyunsaturated fatty acids [22]. On a fresh weight base, it contains about 60% of lipids, among which monounsaturated and polyunsaturated fatty acids account for 85% of the total fatty acids [23]. High oleic acid content provides the food with good stability, and a diet very rich in this fatty acid reduces the concentration of cholesterol [24]. Pistachio samples were also found to contain significant amounts of linoleic (17.7%) acid [25 ,26], an essential fatty acid [20].

Table 4 Fatty acid composition of fresh raw pistachio samples during storage in different packaging systems (%)

Sample	Storage time (day)	14:0	16:0	16:1	18:0	18:1	18:2	20:0	18:3n3	20:1	22:0
CP	First	0.09 ± 0.01	8.6 ± 0.1	0.56 ± 0.01	2.0 ± 0.1	70.7 ± 0.8	17.0 ± 0.6	0.18 ± 0.03	0.28 ± 0.01	0.48 ± 0.01	0.10 ± 0.00
	10th	0.09 ± 0.00	8.4 ± 0.3	0.59 ± 0.02	1.9 ± 0.0	71.2 ± 0.5	16.9 ± 0.3	0.18 ± 0.01	0.28 ± 0.01	0.46 ± 0.03	nd
	20th	0.09 ± 0.01	8.9 ± 0.1	0.56 ± 0.02	2.0 ± 0.1	71.4 ± 0.9	16.1 ± 0.3	0.19 ± 0.01	0.26 ± 0.02	0.46 ± 0.01	nd
	30th	0.09 ± 0.01	9.3 ± 0.2	0.58 ± 0.01	2.0 ± 0.0	70.5 ± 1.0	16.5 ± 0.4	0.19 ± 0.00	0.27 ± 0.01	0.45 ± 0.01	0.11 ± 0.01
MAP	First	0.09 ± 0.01	8.6 ± 0.4	0.56 ± 0.03	2.0 ± 0.0	70.7 ± 0.7	17.0 ± 0.8	0.18 ± 0.01	0.28 ± 0.02	0.48 ± 0.01	0.10 ± 0.00
	10th	0.09 ± 0.00	8.7 ± 0.1	0.57 ± 0.01	1.9 ± 0.0	71.4 ± 0.6	16.2 ± 0.2	0.19 ± 0.02	0.29 ± 0.02	0.46 ± 0.02	0.10 ± 0.01
	20th	0.09 ± 0.01	8.8 ± 0.1	0.56 ± 0.01	2.0 ± 0.0	71.7 ± 0.8	15.9 ± 0.5	0.18 ± 0.02	0.26 ± 0.00	0.46 ± 0.02	nd
	30th	0.09 ± 0.00	9.3 ± 0.0	0.57 ± 0.01	2.0 ± 0.1	71.4 ± 0.9	15.8 ± 0.8	0.18 ± 0.02	0.27 ± 0.01	0.46 ± 0.03	nd
VP	First	0.09 ± 0.00	8.6 ± 0.1	0.56 ± 0.02	2.0 ± 0.0	70.7 ± 1.0	17.0 ± 0.4	0.18 ± 0.01	0.28 ± 0.01	0.48 ± 0.01	0.10 ± 0.02
	10th	0.09 ± 0.01	9.5 ± 0.5	0.55 ± 0.03	2.0 ± 0.1	71.2 ± 0.9	15.6 ± 0.5	0.18 ± 0.02	0.32 ± 0.00	0.45 ± 0.01	0.10 ± 0.01
	20th	0.09 ± 0.00	9.5 ± 0.1	0.57 ± 0.01	2.1 ± 0.0	70.6 ± 0.4	16.1 ± 0.5	0.20 ± 0.01	0.30 ± 0.01	0.45 ± 0.02	0.11 ± 0.01
	30th	0.09 ± 0.01	8.6 ± 0.1	0.58 ± 0.01	2.0 ± 0.1	70.6 ± 0.6	17.0 ± 0.3	0.19 ± 0.01	0.29 ± 0.02	0.47 ± 0.02	0.10 ± 0.00

nd: not detected, CP: conventional packaging, MAP: modified atmosphere packaging, VP: vacuum packaging; analysis were carried out in triplicate.

5. Conclusions

Pistachio nuts are known to have a high content of polyphenols, e.g., anthocyanins, flavonols, proanthocyanidins, and isoflavones, all of which are potent antioxidants and may have protective effects against diseases related to free radical overproduction, such as cancer and cardiovascular diseases [27,28,29].

These different findings (polyphenols) can be explained by both intrinsic and extrinsic factors known to influence the chemical profile and biological properties of Phyto-complexes. Barreira and Ferreira [2008] have reported that climate, agricultural conditions, and processing methodologies result to differences in chemical compositions [28].

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