Journal of Plant Physiology and Breeding

2023, 13(1): 1-16 ISSN: 2008-5168

Research paper

Improving fresh pistachio quality by postharvest application of edible coating during cold storage

Sima Afrashteh, Fatemeh Nazoori*, and Seyed Hossein Mirdehghan

Received: August 12, 2022 Accepted: November 7, 2022
[1]Department of Horticulture, Faculty of Agriculture, Vali-e-Asr University of Rafsajan, Rafsajan, Iran
*Corresponding author; Email: f.nazoori@vru.ac.ir

Abstract
Fresh pistachio fruits of 'Ahmad Aghaei' variety were sprayed with 1% calcium oxide (CaO), 10 mM w/v γ-aminobutyric acid (GABA), 1% carboxymethyl cellulose (CMC), and their combination (CMC+GABA+CaO) for 30 s at room temperature. Spraying with distilled water was considered as the control. Following the drying of fruits at room temperature, they were packed in perforated polyethylene terephthalate and kept under cold storage (at 2 ± 1 ˚C with 85 ± 2% RH) for 75 d. The result showed that the fruit coated with CMC+GABA+CaO, CaO, and GABA exhibited the highest lightness index of the pistachio hulls compared to the control. The highest hue index of the hulls and carotenoids was observed in the fruits coated with CMC+GABA+CaO. The flavonoids in the fruits treated with CaO, GABA, and CMC were significantly higher than in other coatings. At the end of the cold storage, the fruits covered with CMC resulted in considerably higher lipid content than other coatings and the control. Pistachios treated with CMC+GABA+CaO showed lower H2O2 in hulls and kernels and the highest kernel carotenoid, and color indices than the control. In conclusion, the fruits coated with edible layers, especially with CMC+GABA+CaO, can be stored at 2±1 ºC around 50 days to preserve the important traits of the pistachios.

Keywords: carotenoid; flavonoid; fruit decay; color index

How to cite: Afrashteh S, Nazoori F, and Mirdehghan SH, 2023. Improving fresh pistachio quality by postharvest application of edible coating during cold storage. Journal of Plant Physiology and Breeding 13(1): 1-16.

Introduction

Pistachio kernel (*Pistacia vera* L.) has nutritional value such as vitamins, minerals, protein, and essential unsaturated fatty acids (Molamohammadi *et al.* 2019). This fruit is consumed as dried, salted, roasted, and fresh. Consuming fresh pistachios is increasing, but the low storage period is a limiting factor (Gheysarbigi *et al.* 2020). Some authors have shown that the application of the edible coating and preservative compounds such as Ca, γ-aminobutyric acid (GABA), and carboxymethyl cellulose (CMC), result in increasing the storability of horticultural products (Koushesh Saba *et al.* 2016; Ebrahimzadeh *et al.* 2019; Panahirad *et al.* 2019; Rastegar *et al.* 2020). Studies reported that the application of calcium treatment effectively maintained the quality of peaches (Rahman *et al.* 2016) and apricot (Koushesh Saba *et al.* 2016) during cold storage by strengthening the cell wall structure. Solimani Aghdam *et al.* (2022) showed that the consumption of GABA preserved the postharvest quality of the fresh-cut horticultural crops by stimulating the activity of the GABA shunt, synthesis of malate, and delaying fruit ripening. CMC coating has prolonged the storage of different fruits by reducing the decay compared to the untreated fruits (Panahirad *et al*. 2019; Khodaei *et al.* 2021; Razavi *et al.* 2021). This study was conducted to investigate the single and combined effects of some compounds (CMC, CaO, and GABA) on increasing the cold storage life of the fresh pistachio fruit.

Materials and Methods

Plant material and treatments

The 'Ahmad Aghaei' pistachio fruits were packed from a commercial orchard in Rafsanjan, Iran, and transferred to the lab. When 70-80% of the color of pistachio fruit changes, the hull is easier to remove. Pistachios were separated from the cluster to remove the decayed and deformed fruits. Then, the fruits were randomly divided into five groups with three replications, containing 250 g of the fresh pistachio in each experimental unit. Fresh in-hull pistachio fruits were sprayed with CaO1%, GABA10 mM, and CMC1%, their combination (CMC+GABA+CaO), and distilled water (control) for 30 s. Following the fruits treatment and drying, pistachios were packed in the perforated polyethylene terephthalate containers wrapped with low-density polyethylene and stored at 2 ± 1 ˚C with 85 ± 2% RH for 75 d. Characteristics such as the moisture content, water activity, fruit decay, lipids, flavonoids, hydrogen peroxide (H2O2), carotenoids, and color were examined on the pistachio kernels and hulls at 0, 25, 50, and 75 days after storage.

Moisture content

To determine the moisture content, 5 kernels and 15 fresh hulls were used. The weight of each sample was recorded on the first day and after drying for two days at 40 °C. The accumulative weight loss was determined from the difference between the weight on the first day and the weight after drying and was expressed as a percentage of the original moisture content (Nazoori *et al.* 2021).

Fruit decay

Percent fruit decay was measured by counting the spoiled pistachio and surface deterioration at each sampling period. Percent pistachio decay was calculated by the following formula*:*

$$\text{Decay (\%)} = \frac{\text{Number of Spoiled fruits}}{\text{Total number of fruits}} \times 100$$

Fruit color

The color index was estimated by a color meter (Minolta Chroma Meter Model CR-400, Minolta, Japan). The color was measured as light, red-green (a*), and blue-yellow (b*). The chroma value and hue angle were calculated by the following formulae (Gheysarbigi *et al.* 2020):

$$\text{Chroma} = \sqrt{(a*)^2 + (b*)^2}$$

$$\text{Hue angle} = \tan^{-1}(\frac{b*}{a*})$$

Total carotenoids content (kernel)

Total carotenoid contents were measured at 510 and 480 nm and calculated using the following equation:

$$\text{Carotenoids (mg g}^{-1}\text{FW)} = [7.6\ (OD480) - 1.49\ (OD510)] \times [V/1000 \times W]$$

W= sample weight

V= the volume of acetone consumed

H2O2 determination

To measure H2O2, the fresh kernel and hull tissues were homogenized in a mortar with a pestle in 0.5 ml of trichloroacetic acid 0.1 %. The homogenate was centrifuged at 20000 g for 15 min at 4 °C. The supernatant (0.5 ml) was added to the reaction medium containing 0.5 ml 10 mM phosphate buffer and 5 ml 1 molar potassium iodide. Absorbance was determined at 390 nm by a UV-Vis spectrophotometer, and results were expressed as µmol per gram of fresh weight (Palma and Garrido 2016).

Flavonoids content

Flavonoid concentration was measured by homogenizing 1 g of the fresh kernel tissue from each replication. To measure the flavonoid content, 500 µL of the extract reached the final volume of 5 mL with distilled water, then 300 µL of 5% NaNO2 was added. The absorbance was recorded at 415 nm using a spectrophotometer. Quercetin was used as the standard for the creation of the calibration curve. The results were expressed as mg QE 100 g^{-1} (Rastegar *et al.* 2020).

Lipid content

For the lipid content, 1 g of each sample was homogenized in 3 ml of the extraction solution, containing chloroform and methanol (in a ratio of one to two). Then, another 1 ml of chloroform was added. The mixture was passed through the filter paper. Then, 2 ml of distilled water was added, and it was left until the separation of aqueous and organic phases. The aqueous layer was carefully collected, and 1 ml of the organic layer was transferred to a clean tube whose weight was recorded. The next day, the lines were weighed, and the total lipids in the tissues were calculated based on the difference in weight. The results were expressed as mg g-1 fresh weight (Barden and Decker 2016).

Water activity

To measure the water activity with a water activity meter (Novasina, Switzerland), 1 g of kernels or hulls was used (Guadarrama-Lezama *et al.* 2014).

Statistical analysis

This experiment was conducted as factorial with edible coating compounds (CaO1%, GABA10 mM, CMC1%, CMC1%+GABA10 mM+CaO1%, and control) and storage time (25, 50, and 75 days) based on a completely randomized design with three replications. SAS 9.4 version software was used to do the analysis of variance and compare the means by the LSD test at $p \leq 0.05$. Excel software was used to draw the graphs.

Results and Discussion

Moisture content

According to the results of the analysis of variance (Table 1), the main effects of edible coating and storage period on kernel and hull moisture were significant at the 1% probability level. The kernel and hull moisture content decreased from 43.46% and 71.68% to 26.14% and 53.07% in 25 days to 75 days of cold-stored fruits, respectively (Table 2). The fruits coated with CMC exhibited the maximum hull moisture content (68.76%) compared to CaO (61.7%) and the control (61.61%) (Table 3).

Moisture content is one of the most critical factors in maintaining the quality of the products during storage (Sheikhi *et al.* 2019, Gheysarbigi *et al.* 2020). In general, the use of wax or coating on the fruit causes a change in the atmosphere around the fruit. This condition reduces the vapor difference between the juice and the atmosphere around the fruit, resulting in reduced evapotranspiration. A study demonstrated the loss in the moisture content and weight as the effect of coating on various fruits such as pistachios covered with the thyme essential oil along with alginate coating (Hashemi *et al.* 2021), the grape coated with CMC (Yinzhe and Shaoying 2013), strawberries coated with CMC (Khodaei *et al.* 2021), and hazelnut coated with CMC enriched with *Thymus vulgaris* L. extract (Razavi *et al.* 2021). In the present study, the CaO treatment could not maintain hull moisture during storage. However, it has been suggested that the enhanced fruit quality by Ca^{2+} is mainly due to the maintenance of structural rigidity of the cell wall, creating bridges between pectin residues and causing cell-to-cell adhesion (Liu *et al.* 2017). The decreased fruit moisture with calcium is consistent with the results of other researchers (Singh *et al.* 2016 and 2021), which showed the calcium treatment increased lenticel breakdown in apples.

Researchers have indicated that reduced cuticle density and wax deposition by Ca is due to lower expression of genes involved mainly in the wax biosynthesis export. The reduction in the cuticle density and wax causes micro-crack formation and possibly increases the lenticel breakdown on the surface of the apple fruit (Singh *et al.* 2021). GABA also decreases the weight loss of fruits by maintaining the integrity of the membrane, decreasing

Table 1. Analysis of variance of the effects of edible coating on various traits of pistachios during the storage of the 'Ahmad Aghaei' variety.

Sources of variation	Degrees of freedom	Mean squares							
		Moisture (kernel)	Moisture (hull)	Fruit decay	Kernel lightness	Hull lightness	Hue angle (kernel)	Hue angle (hull)	Lipids
Coating (C)	4	342.2**	125.6**	844.0**	14.56	146.5**	0.0070*	0.270**	0.17**
Storage time (S)	2	1129.9**	1322.2**	5183.9**	77.92	1059.0**	0.0520**	0.0001	0.44**
C * S	8	49.7	25.3	64.6	15.73	46.9	0.0004	0.023*	0.098**
Error	30	33.6	4.3	23.6	3.67	14.4	0.0009	0.004	0.0029
CV (%)		16.5	6.00	14.3	2.6	8.1	0.02	0.04	16.7

*,**: Significant at 5 and 1% probability levels, respectively.

Table 1 continued.

Sources of variation	Degrees of freedom	Mean squares							
		H2O2 (kernel)	H2O2 (hull)	Chroma (kernel)	Chroma (hull)	Water activity (kernel)	Water activity (hull)	Carotenoids (kernel)	Flavonoids (kernel)
Coating (C)	4	12.18**	6.34**	190.8**	48.0**	0.00001	0.000026	0.000087**	6.66**
Storage time (S)	2	27.62**	19.87**	686.4**	114. 9**	0.00003	0.000025*	0.00024**	17.81**
C * S	8	1.07	1.55**	24.8*	10.8**	0.00003	0.000009	0.000027**	0.28**
Error	30	0.28	0.15	3.6	1.18	0.00001	0.000008	0.0000027	0.19
CV (%)		10.5	8.2	7.7	4.3	0.35	0.3	12.3	28. 5

*,**: Significant at 5 and 1% probability levels, respectively.

Table 2. Effect of storage time on physiological properties of the fresh 'Ahmad Aghaei' pistachios stored for 75 days at 2 ± 1˚C and 85 ± 2% RH.

Storage period	Moisture content (kernel)	Moisture content (hull)	Hull lightness	Kernel Lightness	Hue angle (kernel)	Fruit decay	H2O2 (kernel)	Chroma (hull)	Water activity (hull)
0 day	50.02	74.21	55.89	76.02	180.12	0	3.33	26.5	0.965
25day	43.46a	71.68a	54.55a	76.04a	180.22b	21.09c	3.59c	22.87a	0.964a
50day	35.81b	64.54b	48.79b	72.18b	180.3a	37.87b	4.79b	19.99b	0.951b
75day	26.14c	53.07c	30.00c	72.01b	180.32a	58.21a	5.84a	18.97b	0.941c

Means followed by the same letters in each column for each are not significantly different (LSD; $p \leq 0.05$).

Table 3. Effect of CMC, GABA, CaO, and CMC+GABA+CaO on physiological properties of the fresh 'Ahmad Aghaei' pistachios, stored for 75 days at 2±1˚C and 85±2% RH

Characteristics	Edible coating				
	Control	CMC	GABA	CaO	CMC+GABA+CaO
Moisture content (kernel)	30.36cd	42.79a	39.09ab	35.7cb	27.73d
Moisture content (hull)	61.61bc	68.76a	58.86c	61.76bc	64.48b
Hue angle (kernel)	180.33a	180.29b	180.27bc	180.28bc	180.25c
Hull lightness	41.83c	44.63bc	48.14ab	48.57ab	52.39a
H2O2 (kernel)	6.37a	4.58bc	4.17dc	4.77b	3.80d
Chroma (hull)	18.47c	21.34ab	19.88cb	21.10ab	22.26a
Fruit decay	50.62a	44.92ab	39.08bc	35.54c	25.11d

Means followed by the same letters in each row are not significantly different (LSD; $p \leq 0.05$).

metabolic activity, increasing the activity of antioxidant enzymes, and preventing stress during the cold storage period (Wang *et al.* 2014; Solimani Aghdam *et al.* 2015). Research has shown that GABA inhibits the membrane lipid peroxidation by inhibiting the activity of the lipoxygenase enzyme and causes to strengthen the cell wall by expressing genes related to the woody cell wall, including chitinase and β- 1,3- glucanase (Wang *et al.* 2015). The effect of storage conditions and packaging on the dried apricots showed that the moisture content decreased, and the water activity of the product increased in the cold storage conditions because the humidity of the air at the lower temperatures is a bit higher compared to the regular storage, therefore was absorbed by the fruits (Guadarrama-Lezama *et al*. 2014).

Water activity

The effect of storage time was significant on the water activity of the pistachio hulls (Table 1). The water activity of the pistachio hulls decreased during the storage times (Table 2). This decrease can be due to moisture loss, resulting from a decrease in water activity due to the reduction of free water.

Although there was no significant difference between the edible coatings for the water activity, however, Wang *et al.* (2014) indicated that GABA inhibits membrane lipid peroxidation by preventing the lipoxygenase activity and powering the cell wall by expressing cell wall genes, including chitinase and β- 1,3- glucanase. Water activity is a resource for predicting and controlling the storage life of food products. This could be applied to most of the foods with water activity values between 0 and 0.9. Controlling the water activity prevents microbial contamination, increases the storage life, and makes some products to be stored in cold conditions. Water activity affects the rate of destructive chemical reactions because water acts as a solvent that can be self-reactive or change the mobility of reactants through viscosity (Guadarrama-Lezama *et al.* 2014). It was shown that in water activity lower than 0.6, practically all microbial activities such as bacteria, fungi, or yeasts are canceled. Conversely, in the water activity over 0.6, chemical and enzymatic reactions start. For example, water activity between 0.6 and 0.7 is desirable for Millard reactions, which cause browning and color changes. The effects of storage and packaging on dried apricots showed that the moisture content decreased and water activity of the product increased in the cold storage conditions because the humidity at low temperatures is slightly higher than the standard storage, so it is absorbed by fruit (Guadarrama-Lezama *et al.* 2014).

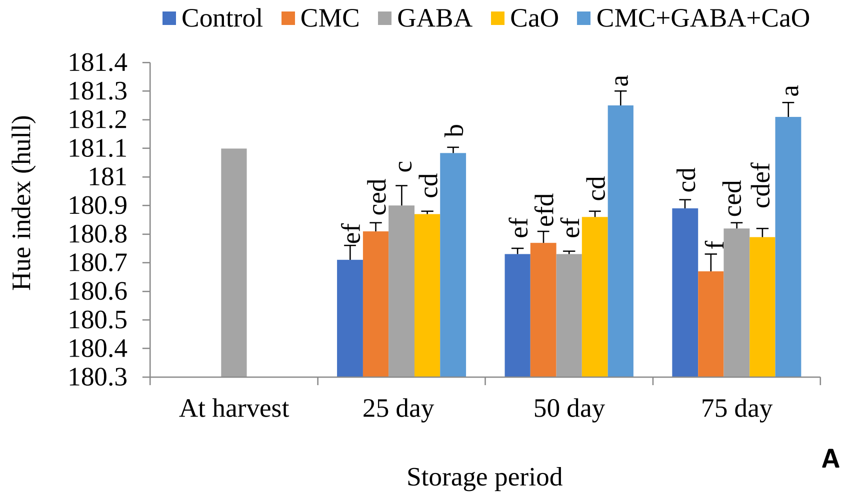
Color index

Table 1 showed the results of the analysis of variance of the color index. Based on the results, the lightness index of hulls and kernels significantly ($p \leq 0.01$) decreased during cold storage (Table 2). The reduction trend of the lightness index shows a darkening tendency in the color of fresh pistachio fruits. Fruits coated with CMC+GABA+CaO, CaO, and GABA exhibited a significantly higher lightness index of pistachio hulls compared to other coatings (Table 3). Hue index (hull) and chroma (kernel) indices were affected by the interaction between the edible coating and the storage period (Figure 1 A, B). The hue index (hull and kernel) was significantly increased during the cold storage in the fruits coated with CMC+GABA+CaO. This coating also exhibited significantly the highest hue index of the hulls compared to the control and other coatings (Figure 1A). The kernel chroma index was increased during the storage times (Figure 1B). Fruits coated with all treatments (except GABA) showed higher levels of the hull chroma index compared to the control after 75 days of storage.

The decrease in the lightness index of the hulls and kernels shows the luminosity, which is probably related to tissue browning via polyphenol oxidase (PPO) activity and membrane loss caused by cold stress. The attendance of O2 can accelerate the browning reaction on the fruit pericarp due to the degradation of anthocyanins and oxidation of the phenolic compounds by PPO and peroxidase enzymes (Yang *et al.* 2017). The benefit of coating in inhibiting the color of fruits arises from their effect on reducing fruit darkening during cold storage. Anti-browning agents prevent the PPO from functioning as a reducing agent. The reduction in the fruit's lightness over time is reported in sweet cherries, while β-aminobutyric acid inhibited this reduction (Wang *et al.* 2015). Similar results were reported in the fresh-cut potato (Gao *et al.* 2018), mango (Rastegar *et al.* 2020), and pomegranate (Nazoori *et al.* 2020), in which the decrease in lightness was lower in the GABA-treated group. Postharvest calcium applications limited flesh browning symptoms in the apricot fruits (Koushesh Saba *et al.* 2016) by reducing ethylene production and reduced activities of pectin modifying enzymes polygalacturonase and pectin-methyl-esterase.

***Fruit* decay**

According to Table 1, the main effects of coating and storage period on the fruit decay were significant at the 1% probability level. Extension of the cold storage period from 25 to 75 days resulted in significantly higher fruit decay (Table 2). All coating treatments significantly decreased the decay percentage



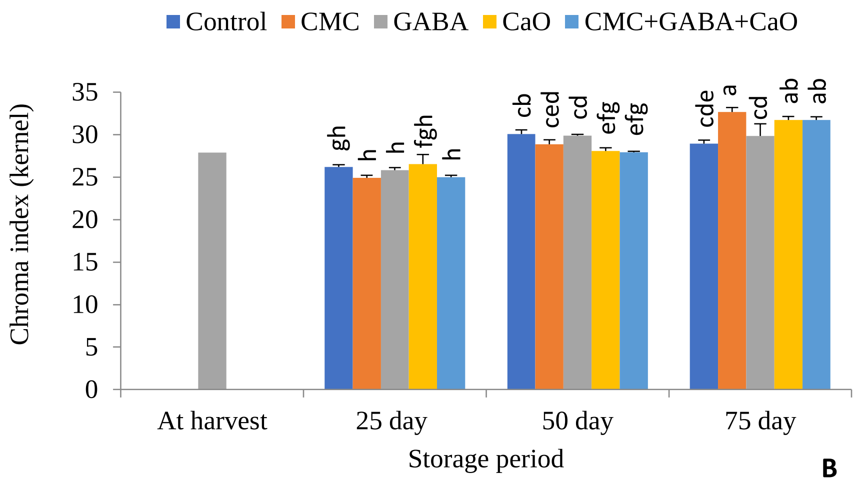


Figure 1. The effect of edible coating and storage time on hue (A) and chroma (B) indices of the fresh pistachios of the ‘Ahmad Aghaei’ variety stored at 2 ± 1 ˚C, 85 ± 2% RH. Vertical bars indicate the standard errors of three replicates.

(except for CMC alone) during the cold storage compared to the control (Table 2). The fruit coated with CMC+GABA+CaO (25.11%) showed the lowest mean decay (Table 3). The physiological and biochemical changes and microbial growth in fresh pistachio fruits can reduce their shelf life (Panahirad *et al*. 2014). Coating and films can slow the deteriorative changes in the coated products by reducing diseases. Previous studies have indicated that CMC (Yinzhe and Shaoying 2013; Razavi *et al*. 2021), GABA (Shang *et al.* 2011; Wang *et al.* 2014; Ebrahimzadeh *et al.* 2019; Rastegar *et al.* 2020), hot water treatment in combination with calcium ascorbate (Aguayo *et al.* 2015) and Ca (Sadr *et al.* 2019), could effectively inhibit postharvest diseases of the fruits by greater firmness, direct inhibition of spore germination, germ tube elongation, and mycelial growth of phytopathogens as well indirect inducement of defense-related enzymes. Throughout the present study, the changes in decay rate occurred more slowly in CMC+GABA+CaO treatment than in the control during the storage period. Alleviation of decay by the GABA treatment was related to the increased proline content and endogenous GABA increased the antioxidant activities (Catalase, superoxide dismutase, and ascorbate peroxidase), and preservation of the membrane integrity via lower phospholipase D and lipoxygenase enzyme activity which coincided with promoting resistance against chilling injury and postharvest pathogens during storage (Yang *et al.* 2017).

Kernel carotenoids

According to Table 1, the main effects of coating and storage period and their interaction were significant at the 1% probability level for the kernel carotenoids. Different coating treatments and storage intervals significantly influence kernel carotenoids. The total carotenoid was significantly decreased during the cold storage period (Figure 2). The fruits coated with CMC+GABA+CaO, exhibited significantly higher carotenoids compared to the control. Pistachio is the only nut with anthocyanin in the testa (pistachio seed coat), and carotenoids and chlorophyll in the kernel (Sheikhi *et al.* 2019). According to Terzo *et al.* (2019), xanthophyll carotenoid content is represented by lutein and zeaxanthin. The use of suitable packaging, edible coating, and adequate storage is critical in preserving the total pigment content of pistachios (Bellomo *et al.* 2009). Some works have reported that CMC coatings also protects against pigment oxidation in other food products such as hazelnut (Razavi *et al.* 2021), plums (Panahirad *et al.* 2019), and walnut (Grosso *et al*. 2018). Contrary to our results, GABA also increased the antioxidant capacity in fruits and vegetables and prevented the destruction of cell membranes, especially pigment membranes (Yang *et al*. 2017).

H2O2

Analysis of variance showed that the coating and storage time had a significant effect on the H2O2 content of the kernels and hulls. Also, the interaction of coating with storage time was significant for the hulls' H2O2 content (Table 1). The H2O2 level of pistachios in kernels and hulls was increased during the storage period (Table 2 and Figure 3, respectively). The fruits coated with distilled water had the highest levels of H2O2 in kernels and hulls compared to all other treatments (Table 3). Fruit covered with CMC+GABA+CaO showed lower H2O2 of the kernels (Table 3) but had no significant difference with the GABA coating. Also, the lowest H2O2 of the hulls belonged to the CMC+GABA+CaO coating 75 days after

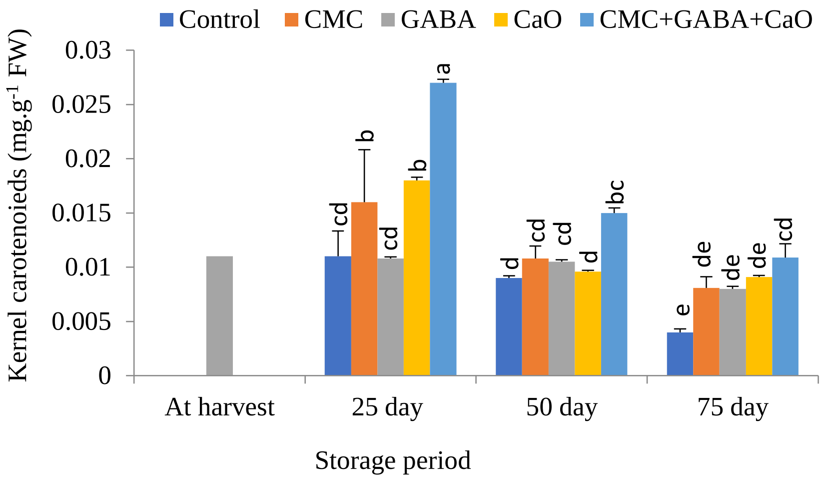


Figure 2. Effect of coating and storage time on kernel carotenoids of the fresh pistachios of the ‘Ahmad Aghaei’ variety stored at 2 ± 1 ˚C, 85 ± 2% RH. Vertical bars indicate the standard errors of three replicates.

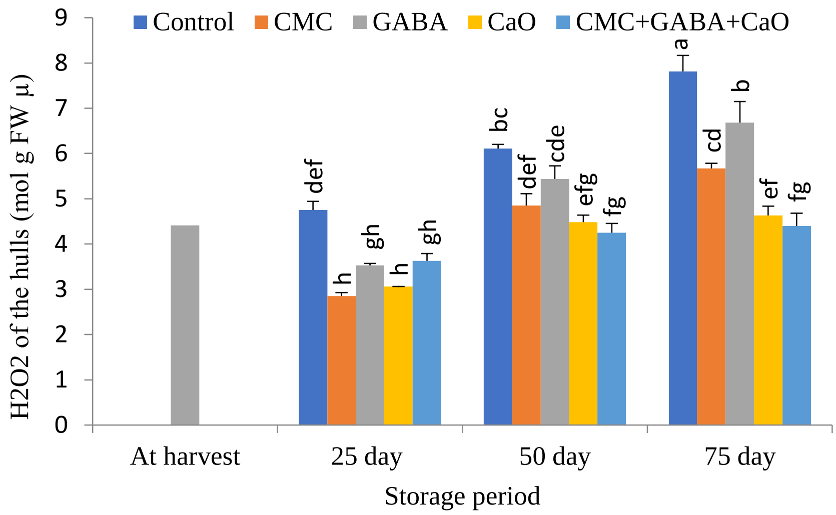


Figure 3. Effect of coating and storage time on the hulls H2O2 of the fresh pistachios of the ‘Ahmad Aghaei’ varietiy stored at 2 ± 1 ˚C, 85 ± 2% RH. Vertical bars indicate the standard errors of three replicates.

storage but it was not significantly different from the CaO coating.

Owing to higher unsaturated fatty acids content, pistachio kernels are nutritionally valuable in the human diet. However, higher unsaturated fatty acids make pistachio kernels vulnerable to oxidative rancidity under unfavorable postharvest handlings (Hashemi *et al.* 2021). Cold stress increases the leakage of cellular solutions through its influence on membrane permeability. In many studies on the postharvest of horticultural crops, a gradual increase in H2O2 during the storage period was reported (Palma and Garrido 2016; Ebrahimzadeh *et al.* 2019; Nazoori *et al.* 2020). Cold stress and a prolonged storage period result in a reduction in the plasma membrane integrity of the fruit cells and loss of cell turgor, which is related to the changes in the brittleness and firmness of the fruits during storage (Baswal *et al.* 2020; Nasibi *et al.* 2020). Enriching edible coatings with antioxidant coatings such as GABA, CaO, and CMC, and their combination lowers the H2O2 accumulation, resulting in higher membrane integrity revealed by the lower electrolyte leakage and MDA accumulation.

Kernel flavonoids content

According to the analysis of variance, the main effects of edible coating and storage period and their interaction on kernel flavonoids were significant at the 1% probability level (Table 1). The observed changes in the flavonoid content in the fresh pistachio kernels during storage are depicted in Figure 4. The flavonoid content of the kernel tissue increased in both treated and control fruits during storage. After 75 days of storage, the minimum flavonoid content was observed in the control fruits. The flavonoid content in the fruits treated with CaO and GABA was significantly higher than in other coatings.

Flavonoids have potent antioxidant activities and the significant role of these compounds can be cited as inhibitors of the production of the reactive oxygen species. The result of some studies showed that GABA increases the production of antioxidant compounds such as phenol and flavonoids (Rastegar *et al.* 2020). Panahirad *et al.* (2019) approved that decreasing the PPO activity in the coated plums could be the reason for the anthocyanins and flavonoid enhancement.

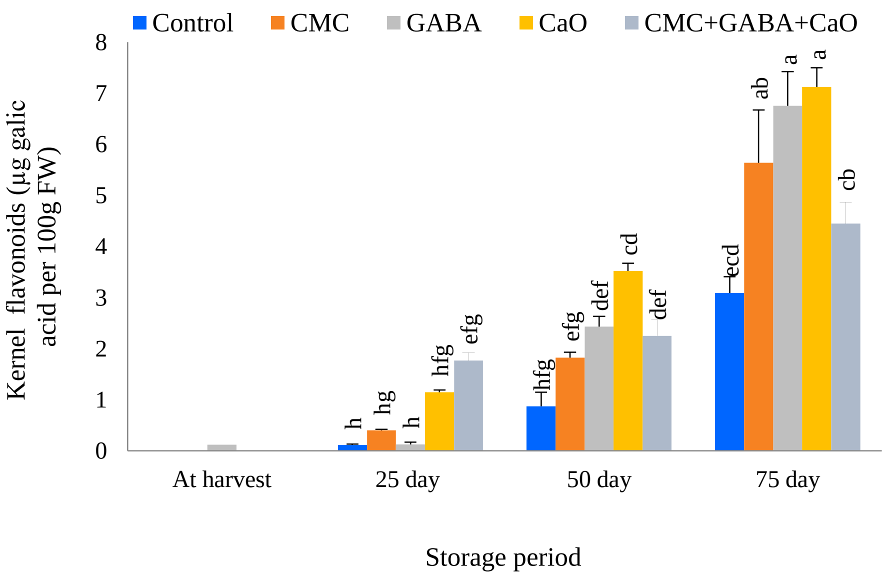


Figure 4. Effect of coating and storage time on the kernel flavonoid content of the fresh pistachios of the ‘Ahmad Aghaei’ variety stored at 2 ± 1 ˚C, 85 ± 2% RH. Vertical bars indicate the standard errors of three replicates.

Lipid content

According to the results of the analysis of variance (Table 1), the effects of edible coating and storage period and their interaction on the kernel lipids were significant at the 1% probability level. Lipid content decreased with the extension of the cold storage period (Table 2 and Figure 5). The fruits coated with CaO showed the highest amount of lipid content at 25 days after cold storage fruit compared to other coatings. However, after 75 days of storage, the cold-stored fruits coated with CMC resulted in considerably higher lipid content than other coatings and the control (Figure 5).

Lipid peroxidation is an important index of the degree of rancidity in nuts. Tissue moisture can help to decrease lipid peroxidation by building hydrogen bonds with lipid hydroperoxides, increasing the oxidative stability of the lipophilic phytochemicals in low-moisture foods (Barden and Decker 2016). At the end of storage time, the reason for the higher lipid content in the CMC coating may be due to maintaining higher moisture in the kernel.

Conclusion

In conclusion, the results showed that the fresh pistachio fruits undergo changes during cold storage, and the use of CMC, CaO, GABA, and CMC+GABA+CaO as edible coating led to the preservation of some characteristics of the fresh pistachios such as color change and antioxidant activity. The fruits coated with CMC+GABA+CaO, CaO, and GABA showed the highest lightness index in the hulls compared to the control. Application of the CMC+GABA+CaO coating decreased the kernel H2O2 and increased the hue angle and kernel carotenoids compared to the control. The coating of the fruits with CaO, GABA, and CMC resulted in significantly higher flavonoids than the control. Also, the decay percentage increased with the extension of the cold storage period but the pistachios treated with the GABA+CaO+CMC coating showed the lowest decay. It appears that pistachio coated with edible layers can be kept for almost 50 days along with preservation of the important traits in cold storage at 2±1 ºC.

Acknowledgment

We thank the Vali-e-Asr University of Rafsanjan for providing the financial resources and equipment necessary for this research.

Conflict of interest

The authors declare that they have no conflict of interest with any organization concerning the subject of the manuscript.

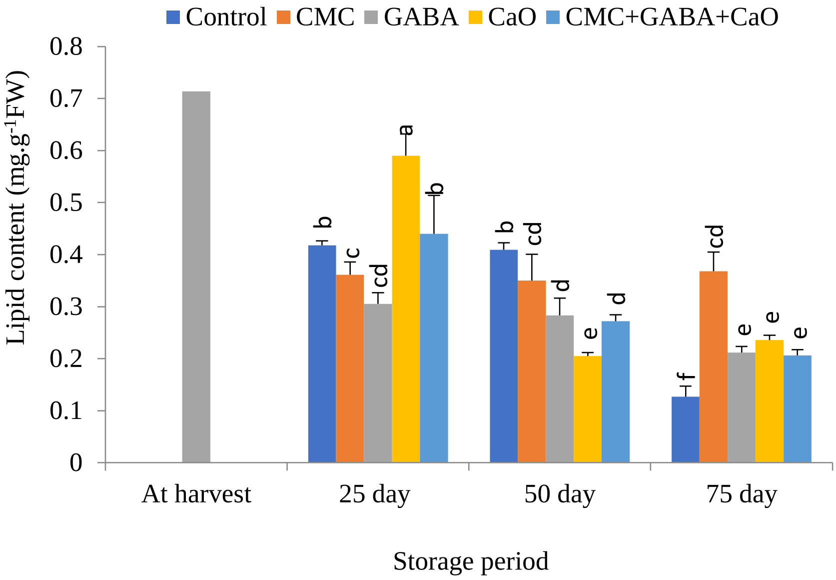


Figure 5. Effect of coating and storage time on the lipid content of the fresh pistachio kernel of the 'Ahmad Aghaei' variety stored at 2 ± 1 ˚C, 85 ± 2% RH. Vertical bars indicate the standard errors of three replicates.

References

Aguayo E, Requejo-Jackman C, Stanley R, and Woolfb A, 2015. Hot water treatment in combination with calcium ascorbate dips increases bioactive compounds and helps to maintain fresh-cut apple quality Postharvest Biology and Technology 110: 158–165.

Barden L and Decker EA, 2016. Lipid oxidation in low-moisture food: a review. Critical Reviews in Food Science and Nutrition 15: 2467–2482.

Baswal AK, Dhaliwal HS, Singh Z, Mahajan BVC, Kalia A, and Gill KS, 2020. Influence of carboxy methylcellulose, chitosan and beeswax coatings on cold storage life and quality of Kinnow mandarin fruit. Scientia Horticulturae 260*:* 108887.

Bellomo MG, Fallico B, and Muratore G, 2009. Stability of pigments and oil in pistachio kernels during storage. International Journal of Food Science and Technology 44(12): 2358–2364.

Ebrahimzadeh A, Pirzad F, Tahanian H, and Soleimani Aghdam M, 2019. Influence of gum arabic enriched with GABA coating on oxidative damage of walnut kernels. Food Technology and Biotechnology 57(4): 554–560.

Gao H, Zeng Q, Ren Z, Li P, and Xu X, 2018. Effect of exogenous γ-Aminobutyric acid treatment on the enzymatic browning of fresh-cut potato during storage. Journal of Food Science and Technology 55(12): 5035–5044.

Gheysarbigi S, Mirdehghan SH, Ghasemnezhad M, and Nazoori F, 2020. The inhibitory effect of nitric oxide on enzymatic browning reactions of in-package fresh pistachios (*Pistacia vera* L.). Postharvest Biology and Technology 159: 110998.

Grosso AL, Asensioa CM, Nepoteb V, and Grossoa NR, 2018. Quality preservation of walnut kernels using edible coatings. Grasas Aceites 69(4): 281.

Guadarrama-Lezama AY, Jaramillo-Flores E, Gutiérrez-López GF, Perez-Alonso C, Dorantes-Álvarez L, and Alamilla-Beltrán L, 2014. Effects of storage temperature and water activity on the degradation of carotenoids contained in microencapsulated chili extract. Drying Technology 32(12): 1435–1447.

Hashemi M, Dastjerdi AM, Shakerardekani A, and Mirdehghan SH, 2021. Effect of alginate coating enriched with Shirazi thyme essential oil on quality of the fresh pistachio (*Pistacia vera* L.). Journal of Food Science and Technology 58(1): 34–43.

Khodaei D, Hamidi-Esfahani Z, and Rahmati E, 2021 Effect of edible coatings on the shelf-life of fresh strawberries: a comparative study using TOPSIS-Shannon entropy method. NFS Journal 23: 17–23.

Koushesh Saba M, Arzani K, and Barzegar M, 2016. Impact of postharvest calcium treatments on storage life, biochemical attributes and chilling injury of apricot. Journal of Agricultural Science and Technology 18(5): 1355–1366.

Liu H, Chen F, Lai S, Tao J, Yang H, and Jiao Z, 2017. Effects of calcium treatment and low temperature storage on cell wall polysaccharide nanostructures and quality of postharvest apricot (*Prunus armeniaca*). Food Chemistry 225: 87–97.

Molamohammadi H, Pakkish Z, Akhavan HR, and Saffari VR, 2019. Effect of salicylic acid incorporated chitosan coating on shelf life extension of fresh in-hull pistachio fruit. Food Technology and Biotechnology 13(1): 121–131.

Nasibi F, Khodashenas M, and Nasibi N, 2020. Priming with L-arginine reduces oxidative damages in *Carthamus tinctorius* seedlings under the toxic levels of lead. Journal of Plant Physiology and Breeding 10(2): 13–26.

Nazoori F, Zamani Bahramabadi E, Mirdehghan SH, and Rafie A, 2020, Extending the shelf life of pomegranate (*Punica granatum* L.) by GABA coating application. Journal of Food Measurement and Characterization 14(5): 2760–2772.

Nazoori F, Zamani Bahramabadi E, Mirdehghan SH, and Afrousheh M, 2021. Some physiological changes of fresh pistachio upon foliar application of sulfur. Journal of Plant Physiology and Breeding 11(2): 1–13.

Palma F and Garrido D, 2016. Putrescine treatment increases the antioxidant response and carbohydrate content in zucchini fruit stored at low temperature. Postharvest Biology and Technology 118: 68–70.

Panahirad S, Naghshiband-Hassani R, Ghanbarzadeh B, Zaare-Nahandi F, and Mahna N, 2019. Shelf life quality of plum fruits (*Prunus domestica* l.) improves with carboxymethyl cellulose-based edible coating. HortScience 54(3): 505–510.

Panahirad S, Zaare-Nahandi F, Mohammadi N, Alizadeh-Salteh S, and Safaie N, 2014. Effects of salicylic acid on aspergillus infection and aflatoxin B1 accumulation in pistachio (*Pistacia vera* L.) fruit. Journal of the Science of Food and Agriculture 94(9): 1758–1763.

Rahman MU, Sajid M, Rab A, Ali S, Shahid MO, Alam A, Isra M, and Ahmad I, 2016. Impact of calcium chloride concentrations and storage duration on quality attributes of peach (*Prunus persica*). Russian Agricultural Sciences 42: 130–136.

Rastegar S, Khankahdani HH, and Rahimzadeh M, 2020. Effect of γ-aminobutyric acid on the antioxidant system and biochemical changes of mango fruit during storage. Journal of Food Measurement and Characterization 14: 778–789.

Razavi R, Maghsoudlou Y, Aalami M, and Ghorbani M, 2021. Impact of carboxymethyl cellulose coating enriched with *Thymus vulgaris* L. extract on physicochemical, microbial, and sensorial properties of fresh hazelnut (*Corylus avellana* L.) during storage. Journal of Food Processing and Preservation 45(4): e15313.

Sadr S, Mozafari V, Shirani H, Alaei H, and Hamid Pour M, 2019. Selection of the most important features affecting pistachio endocarp lesion problem using artificial intelligence techniques. Scientia Horticulturae 246(4): 797–804.

Shang H, Cao S, Yang Z, Cai Y, and Zheng Y, 2011. Effect of exogenous gamma aminobutyric acid treatment on proline accumulation and chilling injury in peach fruit after long-term cold storage. Journal of Agricultural and Food Chemistry 59(4): 1264–1268.

Sheikhi A, Mirdehghan SH, Karimi HR, and Ferguson L, 2019. Effects of passive-and active-modified atmosphere packaging on physio-chemical and quality attributes of fresh in-hull pistachios (*Pistacia vera* L. cv. Badami). Foods 8: 564-565.

Singh V, Gamrasni D, Ben Arie R, Naschitz S, and Friedman H, 2016. Identification of open lenticels in apples after harvest in relation to lenticel breakdown development during storage. Postharvest Biology and Technology 121: 160–170.

SinghV, Gamrasni D, Parimi P, Kochanek B, Naschitz S, Zemach H, and Friedman H, 2021. Postharvest calcium treatment of apple fruit increased lenticel breakdown and altered cuticle structure. Postharvest Biology and Technology 171: 111331.

Solimani Aghdam MS, Flaherty EJ, and Shelp BJ, 2022. Aminobutyrate improves the postharvest marketability of horticultural commodities: advances and prospects. Frontiers in Plant Science 13: 884572.

Solimani Aghdam MS, Naderi R, Sarcheshmeh MAA, and Babalar M, 2015. Amelioration of postharvest chilling injury in anthurium cut flowers by γ-aminobutyric acid (GABA) treatments. Postharvest Biology and Technology 110: 70–76.

Terzo S, Baldassano S, Felice Caldara G, Ferrantelli V, Dico GL, Mulè F, and Amato A, 2019. Health benefits of pistachios consumption. Natural Product Research 33(5): 715–726.

Wang L, Jin P, Wang J, Jiang L, Shan T, and Zheng Y, 2015. Effect of β-aminobutyric acid on cell wall modification and senescence in sweet cherry during storage at 20°C. Food Chem 175: 471–477.

Wang Y, Luo Z, Huang H, 2014. Effect of exogenous γ-aminobutyric acid (GABA) treatment on chilling injury and antioxidant capacity in banana peel. Scientia Horticulturae 168: 132–137.

Yang J, Sun C, Zhang Y, Fu D, Zheng X, and Yu T, 2017. Induced resistance in tomato fruit by γ-aminobutyric acid for the control of alternaria rot caused by *Alternaria alternata*. Food Chemistry 221:1014–1020.

Yinzhe R and Shaoying Z, 2013. Effect of carboxymethyl cellulose and alginate coating combined with brewer yeast on postharvest grape preservation. ISRN Agronomy ID: 871396.

بهبود کیفیت پسته تازه در انبار سرد با کاربرد پس از برداشت پوشش خوراکی

سیما افراشته، فاطمه ناظوری* و سیدحسین میردهقان

گروه علوم و مهندسی باغبانی، دانشکده کشاورزی، دانشگاه ولی‌عصر رفسنجان، رفسنجان
*مسئول مکاتبه؛ Email: f.nazoori@vru.ac.ir

چکیده

میوه پسته تازه احمدآقایی با اکسید کلسیم (Cao) ۱٪، گاماآمینو بوتریک اسید (GABA) ۱۰ میلی مولار، کربوکسی متیل سلولز (CMC) ۱٪ و ترکیب آن‌ها (CMC + GABA + CaO) به مدت ۳۰ ثانیه در دمای اتاق مه‌پاشی شدند. مه‌پاشی با آب مقطر به عنوان تیمار شاهد در نظر گرفته شد. میوه‌ها پس از خشک شدن در دمای اتاق در ظروف پلی اتیلن سوراخ دار با چگالی کم بسته بندی شدند و به مدت ۷۵ روز در انبار سرد (در دمای ۱±۲ درجه سانتی گراد با رطوبت ۲±۸۵) نگهداری شدند. نتایج نشان داد که میوه‌های پوشش داده شده با CaO، GABA و CMC+GABA+CaOبالاترین شاخص درخشندگی پوست پسته را نسبت به سایر پوشش‌ها نشان داد. بیشترین کارتنوئید و شاخص رنگ پوست در میوه‌های پوشش داده شده با CMC+GABA+CaO نشان داده شد. فلاونوئیدها در میوه‌های تیمار شده با GABA، CaO و CMC به طور معنی‌داری بیشتر از سایر تیمارها بود. در پایان دوره انبارمانی، میوه‌های پوشش‌دار شده با تیمار CMCدر مقایسه با سایر تیمارها و شاهد، افزایش قابل توجه محتوای لیپید در مقایسه با سایر تیمارها و شاهد را نشان دادند. پسته‌های تیمار شده با CMC+GABA+CaO دارای کمترین مقدار پراکسید هیدروژن پوست و مغز و بالاترین کاروتنوئید و شاخص رنگ مغز نسبت به شاهد بودند. به طور کلی، میوه‌های پوشیده شده با لایه‌های خوراکی، به‌ویژه با CMC+GABA+CaO، را می‌توان در حدود ۵۰ روز در دمای ۱±۲ درجه سانتی‌گراد با حفظ ویژگی‌های مهم پسته، نگهداری کرد.

واژه‌های کلیدی: پوسیدگی میوه؛ شاخص رنگ؛ کاروتنوئید؛ فلاونوئید