The Effect of Antioxidant Compounds and Polymer Coatings on the Quality and Shelf Life of Fresh Ahmad Aaghaei Pistachio

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Abstract

Introduction: Due to its taste and nutritional properties, pistachio (*Pistacia vera*) is one of the most popular nuts in the world. One of the problems regarding the storage of fresh pistachios is hull browning. The phenomenon is the result of the formation of complex compounds and colored polymers caused by enzyme reactions, which damage the texture, aroma, taste and even the appearance of the fruit.

Materials and Methods: A study was conducted to investigate the effects of citric acid (0, 1, 1.5 and 2%) and ascorbic acid (0 ,15, 25 and 35 ppm), as well as two types of polyethylene (LDPE) and polystyrene coatings on the shelf life (day zero, 25 and 45) of Ahmad Aghaei pistachio cultivar. The samples were prepared from a pistachio orchard located in gardens in the area of Hozdagh in Kerman province. This experiment was performed with three factors in a factorial design based on a completely random design. Each value is the average of four replications (200-gr in each replicate). Sources of variation were treatment (Ascorbic and Citric acid), polymer coatings (polyethylene and polystyrene) and storage period (0, 25 and 45).

Results: The results indicated significant effects of the treatments, polymer coatings and storage periods on some quantitative and qualitative characteristics of the pistachios. Slight weight loss during storage was observed in samples which were higher in polyethylene (0.45%) coatings compared to polystyrene (0.22%). Treatments did not have a significant effect on the pistachio firmness as compared with the effect of shelf life and coating. The hull firmness decreased (30.5%) during storage, but it first decreased and then increased in the kernel. In addition, the samples in the polystyrene coatings had more rigidity (3.5%) than the pistachios in the polyethylene package. In terms of browning, the appearance of the pistachios in the packaging of polystyrene coatings was more desirable than that of polyethylene coatings

Conclusion: In general, weight loss, firmness, apparent quality, and color indices were better in polystyrene coatings than polyethylene ones.

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1. Introduction

Pistachio is the edible seed of the pistachio tree (*pistacia vera* L.). It is one of the most popular tree nuts of the world and is widely cultivated in dry and hot areas of the Middle East, Mediterranean countries and the USA [1]. The moisture content of fresh pistachios varies between 34-40% (wet basis), and after dehulling and separation processes it must be reduced to 5% (wet basis) for safe storage and further processing. Pistachio nuts dried to 4-6% moisture are very stable and could be held for up to 12 months at temperatures as high as 20 ºC without significant losses in quality attributes [2]. The kernels are a rich source of oil (50- 60%) and contain linolenic and linoleic fatty acids, which are essential for human diet and oleic acid [3].

Pistachio is a nourishing snack, but its fresh consumption is limited to the harvest season. Despite the high nutritional value of fresh pistachio, businessmen and farmers are often unwilling to keep or export it because of fruit decay. Fresh pistachio is considered as a fresh product, and it is noticeable that fresh pistachios decay quickly and have a short shelf life after harvest (35-40 day). They are susceptible to decay, mechanical injury and physiological deterioration. Enzymatic browning is the major factor causing quality loss in pistachio. The browning phenomenon usually damages sensory evaluation of products because it causes changes in flavor, softness, and color. Enzymatic oxidation of phenolic compounds such as polyphenol oxidase (PPO) can be found in the browning of pistachio [4]. The phenomenon is the result of the formation of complex compounds and colored polymers caused by enzyme reactions, which damage the texture, aroma, taste and even the appearance of the fruit.

Using antioxidant compound and packaging is recommended to maintain the quality of fresh pistachio, since it slows down respiration and metabolic activities and retards microbial growth. Ascorbic (AA) and citric (CA) acid have been widely used as anti-browning agents for the processing of fruits and vegetables. The secom pounds are strong antioxidant and chelating agents that inhibit the activity of PPO and reduce oxygen. The action of AA and CA is based on reducing intermediate o-quinones to original phenolic compounds before they undergo further reaction to form pigments [3]. The o-quinones react with AA and CA to produce stable colorless compounds that are effective for the inhibition of enzymatic browning of fruit products. Hence, AA has been used in many juices to improve color and shelf-life. The reduction of pH by using acid is a good way to prevent these types of reactions, since the optimum activity of polyphenol oxidase is between 5 and 7 pH. By adding acids such as ascorbic, citric, malic, or some consumable organic acids, it is possible to inhibit the activity of polyphenol oxidase [5]. Heretofore, various studies [2- 6] have been conducted on the maintenance and storage of fresh pistachios. To date, the effect of citric and ascorbic acids on the shelf storage of Ahmad Aghaei fresh pistachio has not been investigated. Different aspects of pistachio packaging have been evaluated. Raei *et al*. (2010) investigated the effects of different packaging materials, including five layers of compound film, modified polypropylene and metalized plastic and packaging atmosphere, on the quality of roasted pistachio nuts. Results showed that packaging pistachio nuts in metalized film and five-layer films with gases N_2/CO_2 and vacuum conditions better kept the quality of pistachio and extended shelf-life. Raei and Jafari (2011) studied the effect of four packaging materials (cellophane, two and three layers' plastic pouches, and metal cans) on quality attributes of pistachio nuts stored in two temperatures (ambient and 40°C) for 1 year. Results indicated that two and three-layer polymer pouches resulted in higher quality attributes for the stored pistachios. Shaker Ardekani and Karim (2012) evaluated the effect of different type of flexible packaging films (LDPE, PVC, LDPE/PA, PA/PP and PET) on the moisture and aflatoxin contents of whole pistachio nuts during storage at ambient temperature (22–28 °C) and relative humidity of 85- 100% [6].

Given the issues mentioned above and the necessity of conducting a study on the effect of pH reduction and using antioxidant compounds and polymer coating to reduce the rate of browning reaction, the researchers of this study sought to investigate the effect of citric (CA) and ascorbic (AA) acids and two coatings of polyethylene and polystyrene on the durability of Ahmad Aghaei fresh pistachio and some of its qualitative and quantitative characteristics.

2. Materials and Methods

2.1 Fruit

This study was conducted on an important commercial pistachio cultivar called Ahmad-Aghaei. The samples were prepared from a pistachio orchard located in gardens in the area of Hozdagh in Kerman province

2.2. Coatings

Ascorbic (AA) and citric (CA) acids were supplied from Sigma-Aldrich (Steinheim, Germany) as antioxidant solutions. Different concentrations of AA (0, 15. 25, 35 ppm) and CA (0, 1.5% and 2%) were Prepared. Briefly, the solution was prepared by adding an appropriate amount of AA and CA powders to distilled water, heating it at 30°C and stirring it to form a clear solution.

2.3. Preparation of samples and treatments

The fresh Ahmad-Aghaei pistachios were harvested at maturity and transferred to the laboratory, and pistachio fruits were then isolated from the cluster in order to be treated. The antioxidant solution was prepared, and fresh pistachios were immersed in coating solutions for 3 min and were placed in air-dried at room temperature for 1 min. The pistachio was packaged to 200-gr polyethylene and polystyrene polymer packs and stored at 3± 1°C and 85± 5% RH for 45 days. Fruits without coating and distilled water were also placed at the same condition as control. Weight loss, firmness, panel test and color value were evaluated after 0, 25 and 45 days of storage.

2.4. Parameters assay

2.4.1. Weight loss

The percentage of fruit weight loss was measured using the following equation (Eq. 1):

(Eq. 1) Weight Loss Percent= [(Starting weight -second weight) / Starting weight]× 100.

2.4.2. Firmness

Fruit firmness was determined using a pressure tester (Lutron model FG5020) and was expressed as kg force. Connect the probe (8mm) to the machine and put the kernel and hull separately below it, then enter the desired pressure. We placed the plunger on an accurate scale and pressed down slowly until the scale registered a weight that occurs on the pressure tester scale. Several different points of the fruit should be tested in this manner.

2.4.3. Sensory analysis

Sensory analysis was done based on the Hedonic scale; eight trained panelists were selected from the five panels among students and professors. The sensory evaluation form had a score scale from 0 to 5 (5= very bad, 4= bad, 3= not good not bad, 2= very good, 1= excellent). The panelists assessed the parameters of hull and shell pistachio acceptance based on the evaluation forms [5].

2.4.4. Color assay

The hull surface color was measured using the colorimeter (Minolta CR-400 model). Parameters L*, a* and b* were measured. Standard white and black ceramics were used to calibrate the colorimeter [11].

2.5. Statistical analysis

This experiment was performed with three factors in a factorial design based on a completely random design. Each value is the average of four replications (200-gr in each replicate). Sources of variation were treatment (Ascorbic and Citric acid), polymer coatings (polyethylene and polystyrene) and the storage period (0, 25 and 45). The experimental data were subjected to analysis of variance by using the SAS 9.1 statistical software. Mean comparison of data was done using the LSD test.

3. Results and Discussion

3.1. Weight loss

Overall, the rate of weight loss in different samples during the 45-day storage period was negligible. The highest rate of weight loss in day 45 of storage in ascorbic acid (15 ppm concentration) with polyethylene coating was observed at 0.45%, which was not significantly different from ascorbic acid (concentration 35ppm) and citric acid (concentration 1.5%) with the same coating. In comparison, polyethylene coatings revealed a higher weight loss than polystyrene coatings (Fig 1). The lowest rate of weight loss on day 45 was associated with ascorbic acid treatment (35 ppm) with a polystyrene coating. On storage day 25, some treatments including ascorbic acid (concentration 15, 25 and 35 ppm) and citric acid (1% concentration) with polystyrene coating did not differ significantly from day zero, and no weight loss was observed.

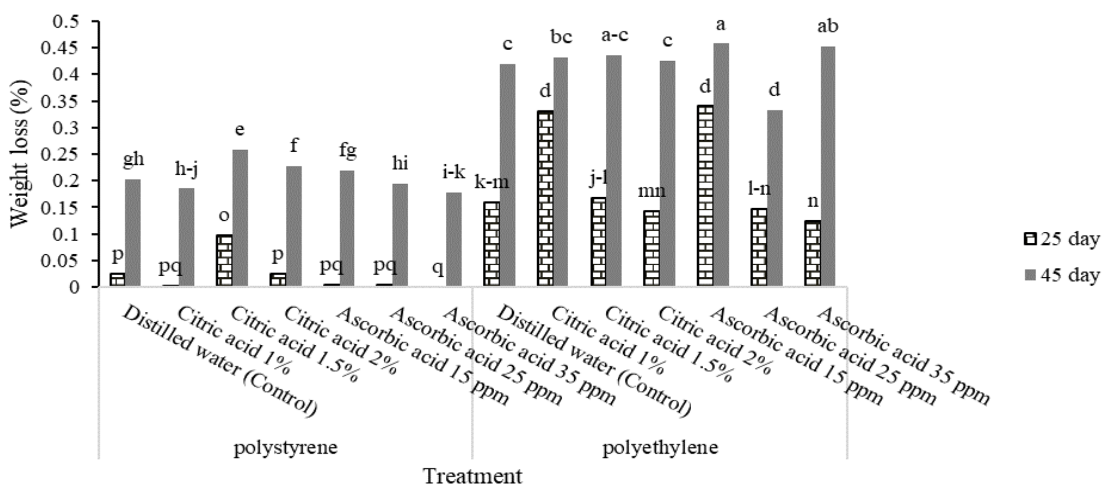

Fig 1. Effects of different concentrations of Ascorbic and Citric acid and polyethylene and polystyrene coatings on weight loss of fresh pistachios during 45 days of storage at 3±1°C and 85±5% RH.

3.2. Firmness

As displayed in Fig. 2 (A), the hull firmness decreased during storage. The firmness of the kernel decreased after 25 days of storage, after which point this factor increased and there was no significant difference between day zero and 45 days of storage (Fig. 2, B). The pistachio kernel firmness in the polystyrene packages were crustier than in the polyethylene packages (Fig. 2, C)

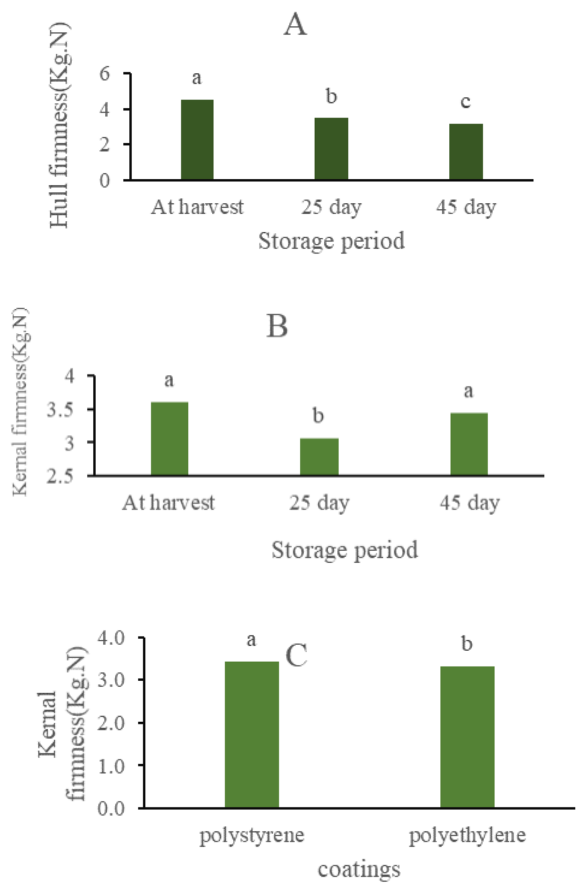

Fig 2. Effect of storage period and polymer coatings typeon firmness of fresh pistachios during 45 days of storage at 3±1°C and 85±5% RH.

3.3. Sensory analysis

During the storage period, the appear ant quality of the pistachio hulls decreased (Table 1). Of the coatings used, packaging with polystyrene coatings had a more favorable appearance than polyethylene coatings. Considering sensory evaluations, treatment with ascorbic acid (15 ppm concentration) with polystyrene packaging retained the superior quality of pistachio hulls, which was not significantly different from the zero storage day. The lowest apparent surface quality of the hulls was observed in ascorbic acid treatment (25 and 35 ppm) with polyethylene packaging on storage day 45 (Table 1).

Table 1: Effect of polymer coatings treatment and of citric acid and ascorbic acid on the hull of fresh pistachio during the storage period

Storage Period		Coating	Control	Citric acid 1%	Citric acid 1.5%	Citric acid 2%	Ascorbic acid 15 ppm	Ascorbic acid 25 ppm	Ascorbic acid 35 ppm
At harvest	25 day	Polystyrene	1.4 m	1.4 m	1.2 mn	1.00 o	0 o	1.10 mn	1.15 mn
		Polyethylene	2.0 l	3.05 a-c	2.75 c-f	2.20 j-l	2.25 h-l	2.20 i-l	2.10 kl
	45 day	Polystyrene	2.55 eh	2.30 i-l	2.55 e-h	2.35 g-k	2.15 j-l	2.85 c-e	2.9 b-d
		Polyethylene	2.45 f-j	2.20 cd	2.65 d-g	2.5 f-i	2.85 cde	4.31 a	3.25 ab

Mean within a column followed by the same letter are not significantly different at p<0.05 according the LSD test

Table 2: Effect of polymer coatings treatment and of citric acid and ascorbic acid on the shell appearance of fresh pistachio during the storage period

Storage Period		Coating	Control	Citric acid 1%	Citric acid 1.5%	Citric acid 2%	Ascorbic acid 15 ppm	Ascorbic acid 25 ppm	Ascorbic acid 35 ppm
At harvest	25 day	Polystyrene	0.85 d-h	0.65 g-l	0.70 f-k	1.15 bc	0.65 g-l	1.10 bcd	1.15 bc
		Polyethylene	0.75 e-j	e-i 0.80	0.95 c-f	0.95 c-f	0.85 d-h	0.40 l	0.60 h-l
	45 day	Polystyrene	0.90 c-g	0.55 i-l	0.50 jkl	1.00 b-e	0.50 jkl	0.75 e-j	1.10 bcd
		Polyethylene	0.45 kl	1.15 bc	1.25 b	1.70 a	0.95 c-f	1.55 a	3.25 ab

Mean within a column followed by the same letter are not significantly different at p<0.05 according the LSD test

3.4. Color assay

The lightness value (L*) of the pistachio shells increased during the storage period, influenced by the coatings and treatments used. On the 25th day of storage, L* increased in both types of packaging with different treatments. The highest amount of this factor was related to treatment with citric acid (1.5% concentration) in polyethylene packaging and ascorbic acid (15 ppm concentration) in both packaging. The least amount was observed on the 45th day of storage in the control treatment with polystyrene packaging (Fig. 3).

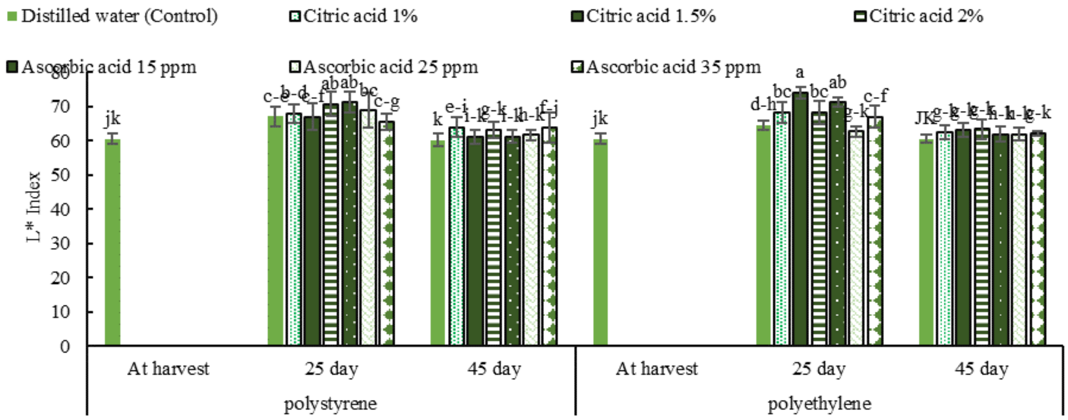

Fig 3. Effects of different concentrations of Ascorbic and Citric acid and polyethylene and polystyrene coatings on L*Value of shell pistachios during 45 days of storage at 3±1°C and 85±5% RH.

Of the two packagings used, the a* value in the polyethylene packaging was lower than that of the polystyrene. On the 45th day of storage, a* rate in the polyethylene packaging was not significantly different from the zero storage day, but in the polystyrene packaging this factor was more than the zero day (Fig. 4).

The highest amount of a* of the shells was observed on day 45 of storage with ascorbic acid (15 and 35 ppm) and citric acid (1.5% concentration) treatments. The lowest amount was observed on day 25 of storage with ascorbic acid (concentrations 15 and 25 ppm) and citric acid (1.5%concentration) treatments.

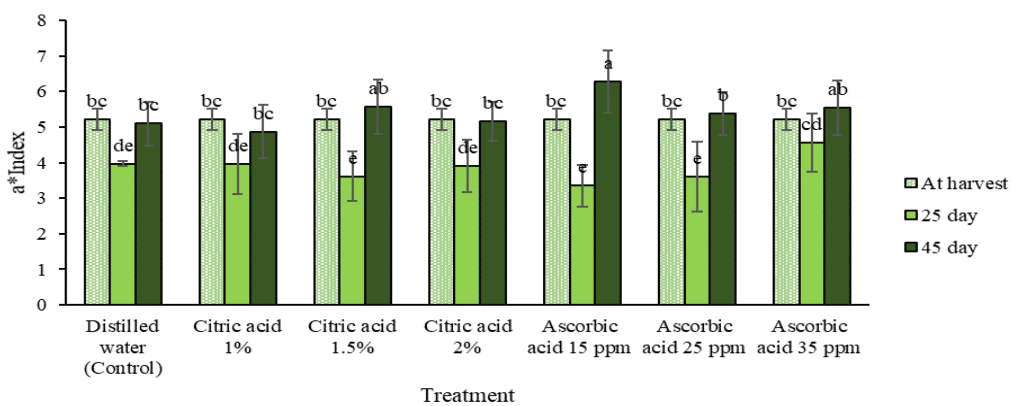

Fig 4. Effects of different concentrations of Ascorbic and Citric acid on a*Value of shell pistachios during 45 days of storage at 3±1°C and 85±5% RH

Based on the results, the b* value of pistachio shells first decreased during the storage period and then increased. The highest amount of this factor was observed on day 45 of storage in ascorbic acid (15ppm concentration) with the polystyrene packaging (Fig. 5). On day 45 of storage, in control treatments (distilled water), citric acid (1% concentration) and ascorbic acid (concentrations of 15 and 25 ppm) with polyethylene packaging, the level of this value was high and was no significantly different from the ascorbic acid (15 ppm) treatment with polystyrene packaging. The lowest b* values were observed on day 25 of storage in ascorbic acid (15ppm) and citric acid (1.5% concentration) with polyethylene packaging

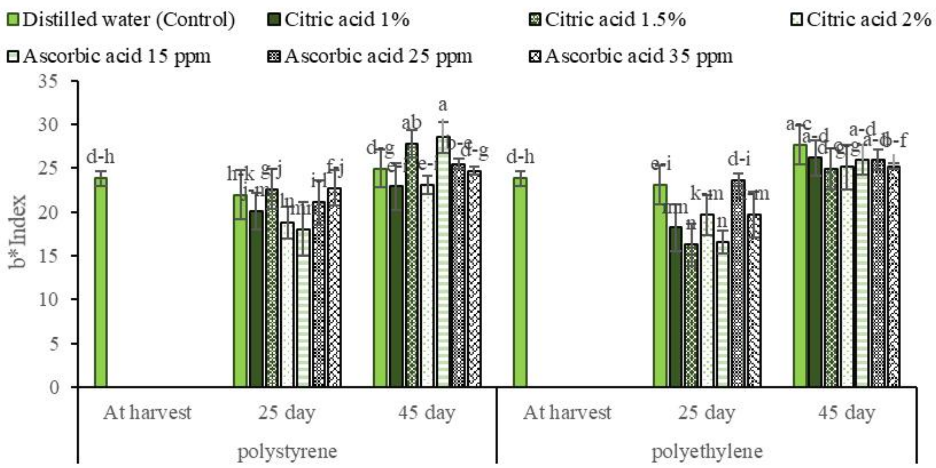

Fig 5. Effects of different concentrations of Ascorbic and Citric acid and polyethylene and polystyrene coatings on b*Value of shell pistachios during 45 days of storage at 3±1°C and 85±5% RH

4. Discussion

Weight is one of the most important fruit properties during storage. Weight loss mainly occurs due to water loss caused by transpiration and loss of carbon reserves due to respiration. The rate at which water is lost depends on the water pressure gradient between the fruit tissue and the surrounding atmosphere. Weight loss in fruit depends on the skin structure and the nature of the wax on the fruit surface [13]. The fruits with excessive water loss suffer from dissatisfaction of the market and customers; therefore, it is important to try to preserve the initial weight of the fruits in the cold store [12]. Moisture content of pistachio nuts in different polymer coatings was statistically significant, in a way samples packed in polystyrene coatings indicated the lowest change in moisture content, whereas samples packed in polyethylene coatings indicated the highest changes in moisture, as shown in Fig.1. Raei et al. (2010) reported that by decreasing moisture content crispness and tenderness of the pistachio nut will significantly be affected. The reason for the inconsiderable weight loss in both types of packaging in the present study can be due to the impermeability of these polymer coatings to steam.

Firmness is an important factor that influences the consumer acceptability of fresh fruit. Pistachio hull and kernel harden considerably during storage, which contributes greatly to its short postharvest life and susceptibility to browning [12]. Fruits lose their firmness during the storage period, which leads to the loss of final quality, as one of the main factors in determining the deterioration of the fruits is the degree of their softening that can reduce the transfer and storage duration [15]. Polyethylene and polystyrene coatings slowed softening, probably due to the effects of polymer coating son the fruit, which acts as a barrier for O_2 uptake thereby slowing the metabolic activity and, consequently, the senescence process, similar to those reported previously [8]. Although AA is widely studied as an anti-browning agent in fresh-cut fruits, there are few discussions for its effects on fruit firmness, so the mechanism by which AA influence fruit firmness is unclear. The reason for tissue softening can be the solubility of insoluble materials, such as cell membrane elements and starch due to the activity of a variety of degrading enzymes [12].

In general, the appearance of pistachio shell and hull (The presence of black and yellow stains) was better in polyethylene packaging during 45 days of storage than in polystyrene packages. It seems that, with an increase in the concentration of AA and CA, the apparent quality of the shells decreases. The most inappropriate treatment for the quality of shells was the treatment with citric acid (2% concentration) in polyethylene packaging, and the best treatment was with ascorbic acid (25 ppm) on the 25th day of storage with polyethylene packaging (Table 2). The letters have no significant difference at the 1% probability level based on the LSD test. In all the treatments, the factor with polyethylene cover was higher in quality than other coatings; therefore, the atmosphere change around the fruits did not affect their breath intensity and did not affect them in terms of anaerobic respiration [9]. In line with these results, Ben Yehoshua also argued that the use of polyethylene coating would double the life of citrus storage, without the fruit having anaerobic respiration and alcohol production [16]. The results of the studies by Purvis on grapefruit also point to the same issue [17]. On the other hand, in polystyrene packaging, anaerobic respiration occurred due to the less permeability to gases, resulting in the unfavorable taste of the pistachios. Contrary to these results, Davoudi *et al*. (2010) stated that the taste of dried berries in polystyrene packaging was better than in polyethylene [18].

Color is the first attribute of food quality evaluated by the consumers, and is strictly related to quality features such as freshness, maturity, desirability and food safety. Therefore, it is a significant classification factor for most food products and changes in the external color were monitored by measuring lightness ($L*$), $a*$ (redness), and $b*$ (yellowness). The results of the measurements of color parameters $L*$, $a*$, $b*$ of pistachio hull revealed that $L*$, $a*$ value increased in 25 days and the end of storage were decreased. No influence on $a*$ value of pistachio with only polymer coatings was observed. The highest amount of this factor was related to the treatment with citric acid (1.5% concentration) in polyethylene packaging and ascorbic acid (15 ppm concentration) in both packaging. Edible coatings can be effective carriers for anti browning agents withholding the agents on the surface of the fruit tissues. Anti browning agents are commonly incorporated in crosslinking solutions and applied after the adhesion of the edible coating solution on the surface of the fresh fruit [13].

5. Conclusion

Considering the results obtained in the present study, qualitative characteristics such as weight loss, firmness, hull and shell appearance were better retained in polyethylene coatings than in polystyrene coatings. Application of polyethylene coatings whit ascorbic acid 15 and 25 ppm and citric acid1.5% better retained qualitative and physiological properties than the other treatments.

Conflict of interest

The authors declare no conflict of interest.

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