Investigation of Effects of Different Coatings on the Storage of Fresh Fruit in Pistachio Commercial Cultivars

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Abstract

Introduction: Pistachio is one of the major horticultural products of the country, which do not have high storability. Under current conditions, fresh pistachios in Iran are offered in bulk for a limited duration without suitable packaging. The gap between the harvest time and consumption of pistachios significantly decreases their nutritional and economic values under unfavourable conditions. Thus, providing optimal conditions for proper packaging or applying coatings could be one of the appropriate solutions for maintaining the desired quality and increasing the marketability of this economic product of the country.

Materials and Methods: In this study, the effect of various coatings on the quality and storage features of pistachio fresh fruit were examined. This research was carried out as factorial in a completely randomized design with three replications. The experiment was performed on three commercial pistachio cultivars (Akbari, Kaleh-Ghoochi, and Ahmad-Aghaei) under the effects of temperature (cold storage at 4 °C and normal room temperature at 24 °C) and different coatings. Coating conditions included wax B131, wax PCFC9265, wax B131+ wax PCFC9265, transparent plastic, the newspaper, the cotton bag, inside the newspaper and then inside a plastic material, inside newspaper and then inside a cotton bag, inside a cotton bag and then inside newspaper, as well as the control. The studied factors consisted of fruit weight loss, shrinkage percentage, and moldiness percentage.

Results: The results showed a significant difference among the commercial cultivars in the quality features (P< 1%). In this study, the highest percentage of moldiness and fruit weight loss under cold storage conditions was related to the Akbari cultivar during the storage duration. Besides, the highest rate of shrinkage was related to the Kaleh-Ghoochi cultivar. According to the results, the best treatments in the storage duration were treatments 4 and 7. Results of the Kaleh-Ghoochi cultivar showed that the percentage of fruit weight loss and the shrinkage percentage were less in treatment 7 than in treatment 4. In the Akbari cultivar, the moldiness percentage in treatment 7 was reduced by half; in addition, the weight loss percentage was 2% higher than in treatment 4. Results from the Ahmad-Aghaei cultivar showed that the weight loss percentage was very low in treatment 7.

Conclusion: In general, the use of treatments 4 and 7 for 39 days under cold storage conditions helped maintain the appearance features of fresh pistachios.

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1. Introduction

Pistachio (*Pistacia vera* L.) is the most important horticultural products of the country. Because of the favourable climatic conditions of the country, they are unique in terms of quality among other competitors. Pistachio, In Iran, is processed dry under storage conditions and are exported in cotton and polyethylene bags. However, the sale of fresh pistachio has been confined to the local market and surrounding regions [1]. Fresh pistachios do not have high storability. Besides, in the case of the lack of packaging and under improper temperatures, they should be consumed shortly [2]. In this respect, research shows that contamination of fresh pistachio fruit increases upon an increase in the temperature and the storage duration. Ferguson *et al* [3] reported that fresh pistachios could be stored for at least 20 hours at 25 °C without a reduction in the quality of this product. Fresh pistachios could be stored for more than 48 hours only under cold storage conditions. In the case before storage, leaves, damaged pistachios, and other foreign objects prone to spoilage are removed from the product, unskinned pistachios could be stored for a longer duration without damage and spoilage [4]. Results from the study of Kadar *et al* [5] showed that fresh pistachios would become contaminated in the storage duration at 25 and 30 °C after 48 and 18 hours, respectively. Fresh pistachios could be stored at 0 °C with a relative humidity of 80% for more than six weeks with no damage to their appearance. In recent years, much research has been done to reduce infection with aflatoxin-producing fungi. Thus, researching the applications of compounds that on the one hand have no damaging effects on the product, humans and the environment, and the other hand control infection with various types of fungi in the storage duration is of high significance [6, 7]. In Iran, coatings are applied using wax in the storage period of most citrus fruits [8]. Such coatings are applied to preserve fruit after the harvest time and during storage and transportation periods. This compound, in addition to creating a layer on the surface of the fruit, produces a controlled internal atmosphere around the fruit, thereby increasing its storability and preventing attacks by fungal agents. In this context, storage at low temperatures has been reported to be effective in reducing product spoilage [9]. Aminian *et al* [10] reported that the soft surface skin was crushed within two days after the harvest time, with its phenolic compounds having exited. This happened due to respiration by fresh pistachios and the resulting production of heat and moisture from respiration. Thus, there is the possibility of Aspergillus growth and production of aflatoxins in pistachios. Nazoori *et al* [1] reported that any acceleration and delays

of the harvest time, as well as any increase in the storage period and the temperature, would lead to the spottiness of the bony skin of the fruit and a decrease in the fruit storability. With an increase in the storage period and temperature, the kernel damage, acid number, peroxide number, and water loss increase, but the taste index and firmness of the fruit decrease. Based on their reports, by harvesting the crop at the ripening stage of 70 to 80%, fresh pistachios could be stored at 4± 1 °C for 45 days. Rafieidolatabadi [11] examined the effects of various coatings on the storability of fresh pistachio fruit. According to their results, the least fruit weight loss under cold storage conditions was related to the treatment of the mixture of the disinfectant ABF and wax B131. Besides, the fruit had a much lower percentage of moldiness under cold storage conditions than under normal conditions. In addition, the lowest percentage of moldiness was observed in the mixture of the disinfectant ABF and wax B131. The use of wax coatings or disinfectant treatments is among the methods used to increase the storability of crops. These coatings, through creating a thin and continuous layer, prevent entry and exit of substances (water and gases, such as oxygen and carbon dioxide), thereby preventing the growth of microorganisms on the surface of the crop and providing them with mechanical protection [12, 13]. According to the literature review, these coatings are used to increase the storability of food products by creating a barrier against environmental hazards and damage. These coatings can lead to a delay in the reduction of moisture and volatile compounds in the food, reduce respiration intensity, and also delay tissue changes to the crop. Besides, some of these coatings can act as antimicrobial compounds [2, 14, 15]. In recent decades, the use of different coating compounds to increase product storability has been studied [16]. However, in some cases, their use has not been successful depending on the type of the crops and because of creating problems, such as changes in the taste, colour, and firmness of the treated fruits [17]. In general, coating materials are not commonly used in Iran. Besides, poor supply of fruits and significant weight loss make them become quickly withered and be supplied to the consumers under unfavourable conditions. Thus, the application of suitable and cost-effective methods and coatings aimed at reducing the wastes of fresh pistachio as well as an increase in their storability will greatly help solve this problem.

In this study, the effects of various coatings on the quantitative and qualitative features as well as storability of fresh fruits of three commercial pistachio cultivars (Akbari, Kaleh-Ghoochi, and Ahmad-Aghaei) were investigated.

2. Materials and Methods

2.1-Sampling

Fresh pistachio samples were prepared from the three commercial cultivars of Akbari, Kaleh-Ghoochi, and Ahmad-Aghaei. The chosen trees were of the same age (20-year-old), with their rootstock having been Badami-e-Zarand. The harvest was reaped in late September, at the ripening stage of 70 to 80%. Five kilograms of each cultivar were sampled randomly. Just after sampling, the samples were transferred to the laboratory for applying the treatments. After the separation of the clusters in the laboratory, fresh, healthy, and uniform pistachios were separated from unripe, damaged, and cracked ones for treatment application. This research was conducted as factorial in a completely randomized design with three replication. In the disinfectant treatment, immersion was applied as the coating method. Besides, in the wax treatment, pistachios were fully dried and waxed. Next, the dried samples were placed in relevant containers.

Different coating treatments of disinfectants and waxes included:

1- The treatment of wax B131 (the product of Hayat Pooshesh Sabz Co., a domestic product, having a standard approved by the Ministry of Health, which is used for citrus fruits as well. The type of the product is wax, with its product code being B131).

2- The treatment of wax PCFC9265 (the product of Hayat Pooshesh Sabz Co., a domestic product, having a standard approved by the Ministry of Health. The type of the product is wax, with its product code being PCFC9265).

3- The mixed treatment of wax B131 and wax PCFC9265

4- The treatment inside the moderately thick transparent plastic (a zipped transparent plastic bag, moderately thick, with code ZP-2018)

5- The treatment inside the ordinary newspaper

6- The treatment inside a cotton bag

7- The mixed treatment of treatments 5 and 4 (inside the newspaper and then inside the plastic)

8- The mixed treatment of treatments 5 and 6 (inside the newspaper and then inside a cotton bag)

9- The mixed treatment of treatments 6 and 5 (inside a cotton bag and then inside the newspaper)

10- The control

The treatments mentioned above were examined both at the normal temperature (room temperature of 25 °C) and the fridge temperature (4 °C). In this study, a total of 108 transparent plastic containers were utilized for packaging the treated pistachio fruits. In every replicate of different treatments, a total of 100 fresh skinned pistachio fruits were used. The factors examined included the fruit weight, shrinkage percentage, and moldiness

percentage. Besides, shrinkage and moldiness percentages were measured and compared with those of healthy fruits.

2.2- Fruit weight reduction

In order of measuring this index, weight changes of freshly packed pistachio were measured at a four-day interval. Besides, the weight loss percentage was measured using the following equation:

$$\text{کاهش وزن (\%)} = \frac{\text{(وزن ثانویه – وزن اولیه)} \times 100}{\text{وزن اولیه}}$$

Weight Loss = Primary Weight – Secondary Weight / Primary

2.3- Shrinkage and moldiness percentages

Considering the number of healthy fruits and the number of shrunken and moldy fruits, shrinkage and moldiness percentages were calculated once every four days [18]. The cases mentioned above were examined for 52 days. Besides, the samples were statistically analyzed by SPSS software. In addition, the means were compared using Duncan's method at a 5% significance level. Besides, Microsoft Excel was used for drawing the figures.

3- Results and Discussion

Table 1 shows the results from the analysis of variance of the effects of different treatments on fruit weight loss as well as percentages of shrinkage and moldiness in fresh pistachio fruits from Akbari, Kaleh-Ghoochi, and Ahmad-Aghaei cultivars. According to the results, there was a significant difference among different treatments of cultivars, temperatures, coatings, and storage periods in fresh fruit weight loss, as well as shrinkage and moldiness percentages at the probability level of 1%. Based on the results, the studied treatments exerted a significant effect on the fresh fruit weight. The same trend was observed for shrinkage and moldiness percentages in fresh pistachio fruit. Besides, analysis of dual, triple, and quadruple cross impacts of the studied treatments on each other showed the significant trend of the effects of the four treatments on each other at a probability level of 1% (Table 1).

Table 1- Analysis of variance for the effect of different treatments on the studied features in fresh pistachio fruit

Sources of Variation	df	Mean Squares		
		Fruit Weight	Moldiness Percentage	Shrinkage Percentage
Cultivar	2	5067.966**	11876.852*	10408.832**
Polymer Coating	9	38766.872*	103522.422*	194649.619*
Cultivar × Polymer Coating	18	427.064**	917.534**	1411.381**
Temperature	1	41781.582*	675240.417*	23339.63**
Cultivar × Temperature	2	3484.613**	7930.075**	8791.084**
Polymer Coating × Temperature	9	6277.821**	46815.089*	11523.896**
Cultivar × Polymer Coating ×Temperature	18	331.629**	1397.008**	2505.706**
Time	8	8009.453**	16168.719*	26487.043**
Cultivar × Time	16	43.371**	655.311**	1197.363**
Polymer Coating × Time	72	170.586**	1273.1**	1060.48**
Cultivar × Polymer Coating × Time	144	17.006**	71.226**	199.527**
Temperature × Time	8	1170.896**	5342.212**	12057.319**
Cultivar × Temperature ×Time	16	34.689**	716.348**	1406.219**
Polymer Coating × Temperature × Time	72	105.153**	495.166**	1197.52**
Cultivar × Polymer Coating × Time ×Temperature	144	13.263**	82.921**	269.144**
Error	1080	5.37	5.178	9.522
CV (%)	**-**	**3.24**	**7.53**	**5.75**

ns, * and **: Non-significant, significant at 5% and 1%, respectively

Results from comparing the mean effects of coating treatments and cultivar types are given in Table 2. According to the results, the type of cultivar affected qualitative features of storability. Results from comparing the studied cultivars under cold storage conditions indicate that the highest rate of shrinkage in fresh fruit was observed in the Kaleh-Ghoochi cultivar. Besides, the highest percentage of weight loss and moldiness in fresh fruit was related to the Akbari cultivar. In addition, the results indicate that different coatings were significantly effective in reducing fruit weight. The lowest percentages of fresh fruit weight loss were observed in the treatments of plastic, inside the newspaper and then inside plastic, wax, and the control. Besides, the highest mean was related to the treatments of the newspaper, inside newspaper and then inside a cotton bag, and the cotton bag (Table 2; Figs. 1 and 2). The results showed a significant difference in the percentage of shrinkage in pistachio fruit skin treated with different coatings. Accordingly, the highest shrinkage percentage was related to the treatments inside newspaper and inside the cotton bag. In contrast, the lowest shrinkage percentage was observed in the treatment inside then newspaper and then inside plastic, and the treatment inside plastic (Tables 2; Figs. 1 and 2). The moldiness percentage in pistachio fruit was affected by different coatings

Accordingly, the lowest moldiness percentage was related to treatments 4 and 7 (Table 2; Figs. 1 and 2).

Table 2 - Comparison of the means of the studied features of fresh pistachio fruits (6.6 to 7.15)

Cultivar	Temp (˚C)	Control (10)			Plastic Treatment (4)			Newspaper + Plastic Treatment (7)		
		Moldiness (%)	Shrinkage (%)	Weight Loss (%)	Moldiness (%)	Shrinkage (%)	Weight Loss (%)	Moldiness (%)	Shrinkage (%)	Weight Loss (%)
Kaleh-Ghoochi	**Room**	95.66 b	24 a	29.22 b	100 b	0 a	5.2 b	96 b	0 a	5.2 a
	Fridge	1.66 a	83 b	5.56 a	2 a	2.33 b	0.17 a	2 a	5 b	5.34 b
Akbari	**Room**	90.66 b	25.66 a	34.15 a	97.66 b	0 a	9.19 b	86 b	11.69 b	5.71 b
	Fridge	30.66 a	81.66 b	36.28 b	12 a	0 a	3.12 a	24.33 a	0 a	1.05 a
Ahmad-Aghaei	**Room**	91.66 b	42 a	26.84 a	92.33 b	12.33 b	7.34 b	87 b	23.32 b	3.34 a
	Fridge	6 a	76.33 b	28.93 b	7.33 a	0 a	0.91 a	7 a	0 a	4.66 b

Means followed by the same letter are not significantly different at 5% probability level using Duncan's test

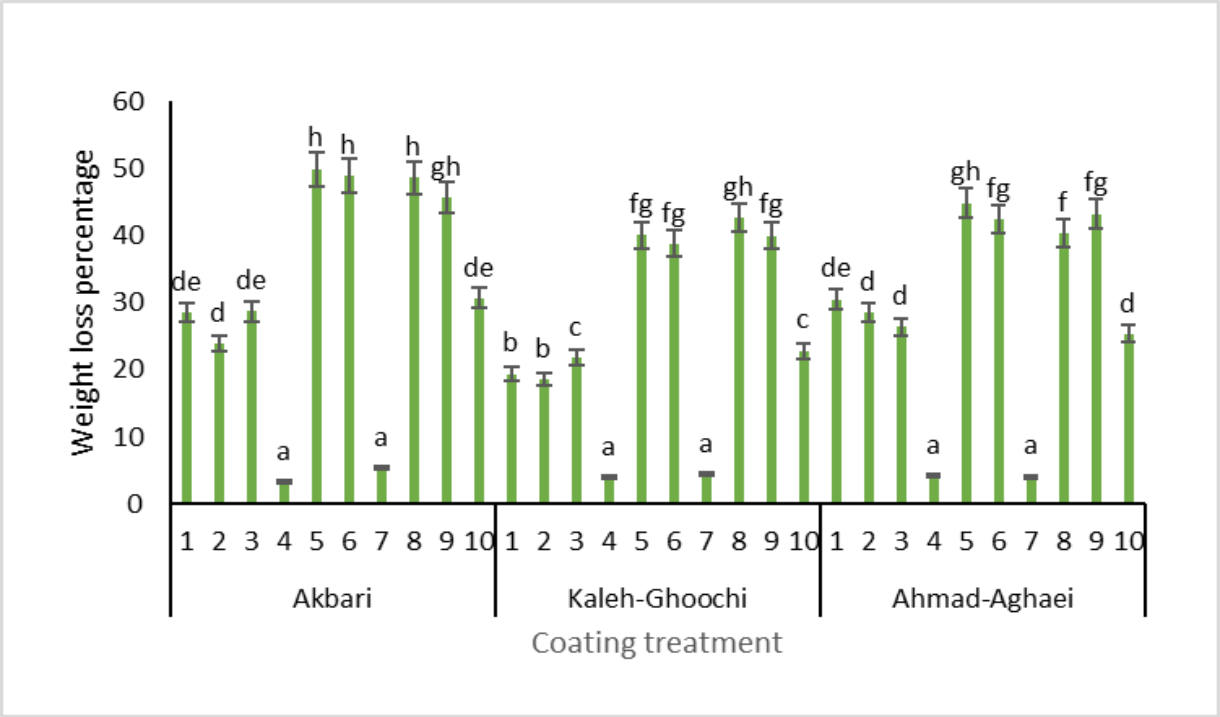

Fig. 1- Showed the results of the weight loss percentage under the effects of coatings and cultivars

Fig. 1- Effects of the applied coating treatments on the weight loss percentage in the cultivars studied (The coating treatments included 1- Wax B131; 2- Wax PCFC9265; 3- Wax B131 and wax PCFC9265; 4- Inside transparent plastic of moderate thickness; 5- Inside ordinary newspaper; 6- Inside a cotton bag of moderate thickness; 7- Mixed treatment of treatments 5 and 4 (inside newspaper and then inside plastic); 8- Mixed treatment of treatments 5 and 6 (inside newspaper and then inside a cotton bag); 9- Mixed treatment of treatments 6 and 5 (inside a cotton bag and then inside newspaper); 10- Control (Means followed by the same letter do not have significantly different at 5% probability level in the Duncan's test).

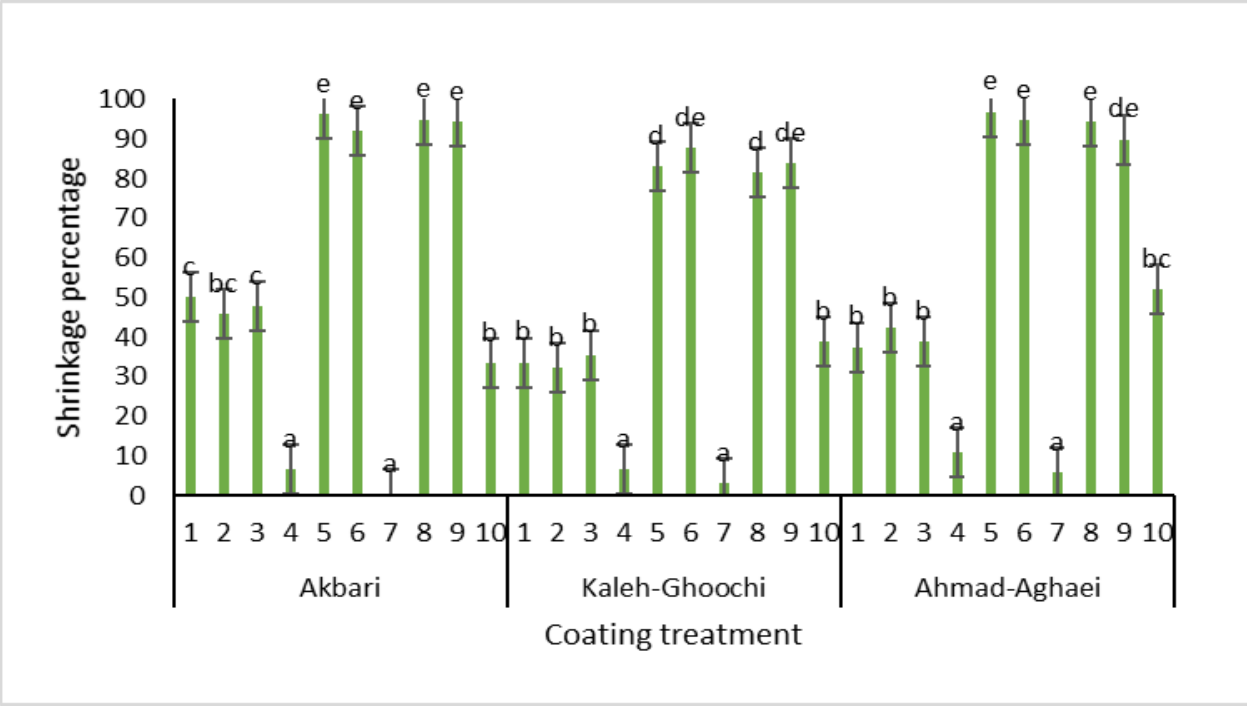

Fig. 2- Effects of the applied coating treatments on the shrinkage percentage in the cultivars studied (The coating treatments included 1- Wax B131; 2- Wax PCFC9265; 3- Wax B131 and wax PCFC9265; 4- Inside transparent plastic of moderate thickness; 5- Inside ordinary newspaper; 6- Inside a cotton bag of moderate thickness; 7- Mixed treatment of treatments 5 and 4 (inside newspaper and then inside plastic); 8- Mixed treatment of treatments 5 and 6 (inside newspaper and then inside a cotton bag); 9- Mixed treatment of treatments 6 and 5 (inside a cotton bag and then inside newspaper); 10- Control (Means followed by the same letter do not have significantly different at 5% probability level in the Duncan's test).

According to the results, the best treatments were coating treatments 4 (transparent plastic of moderate thickness) and 7 (inside newspaper and then inside plastic) under cold storage conditions. Nazoori *et al* [1] investigated the storage of fresh pistachios with soft skin, fresh pistachios without soft skin, and dried ones inside paper bags at 4 and 12 °C. Their research results showed that an increase in the storage duration and the temperature stained the bony skin and reduced the storability of the fresh fruit. With an increase in the storage duration and temperature, water loss increased, yet fruit firmness decreased. Based on their results, storing fresh pistachios with soft skin at 4 °C increased their storability up to 45 days.

Results from the study of Ferguson *et al* [3] showed that unskinned pistachios could be stored for at least 20 hours at 25 °C with no significant color changes in the bony skin. If the pistachios are skinned, they will go rotten after 25 hours at 25 °C or after 18 hours at 30 °C. Therefore, the storability of fresh pistachios decreases with an increase in the storage period and the temperature. A great portion of such damage and changes in the product quality is caused by the activity of enzymes and metabolic changes in the edible tissue [19]. Water loss, the reduction in fruit tissue firmness, the reduction in phenolic compounds, and discoloration have been reported to be among the factors reducing the quality of various products in the storage period and after harvest [20- 22]. Wax coatings, being among common chemical treatments used for the prevention of fruit weight loss in some agricultural products, increase the storability of citrus fruits [23]. Nevertheless, according to the results of the present study, the use of wax is not appropriate for increasing the storability of the pistachio crop. Morshedi [24] studied the effects of the use of ordinary packaging on the Owhadi cultivar. The results showed that the use of polypropylene sack packaging at 4°C with a relative humidity of 50% was the best condition for storing fresh pistachios. Based on the results, in the case of using cotton bags, compared to coating treatments 4 (inside transparent plastic of moderate thickness) and 7 (inside the newspaper and then inside plastic) under cold storage conditions, the rate of water loss was 40%, which was followed by an increase in the rate of crop shrinkage.

4. Conclusion

Considering the export evaluation of this horticultural product of the country, the supply and processing method have significant effects on the quality of fresh pistachio product. Until now, pistachios have been stored dry in cotton and polyethylene bags. While evaluation of

more proper and cheaper storage and packaging methods could certainly be one of the methods of selling fresh pistachios in local, regional, and even export markets. Standard criteria of the fruit quality in recent years have included the quality of internal contents of the fruit and the lack of toxin residues and chemicals inconsistent with the environment. Besides, regarding agricultural products, their market acceptance and appearance have been considered [7]. Accordingly, in this study, the market acceptance of fresh pistachios was investigated in different ultivars. Results from this study showed that the appearance features (fruit weight, shrinkage, and moldiness) of fresh pistachios changed during the storage period, depending on the type of cultivar. Based on the results, coating treatments 4 or 7, under cold storage conditions, had an effective role in maintaining the appearance quality of fresh pistachios for 39 days.

Conflict of Interest

The authors of present researches declare that there is no conflict of interest.

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