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The Effect of Different Types of Coating and Packaging on the Physical Properties of Persimmon Fruit under Load

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Abstract

Since persimmon is a pressure-sensitive fruit and it is difficult to store this fruit in warehouses, in this research, an attempt has been made to examine the parameters affecting the reduction of changes in its physical properties. The samples were loaded at 150 and 250 N, three types of foam container packaging with polyolefin film, polyethylene-terephthalate, and ordinary box, and four types of polyamine putrescine coating with concentrations of 1 and 2 mM, distilled water and uncoated. Properties such as Physiological Weight Loss, volume, and the density of persimmon fruit, as well as the firmness of this fruit in the prepost-storage stage were examined. The results showed, the highest firmness was obtained in the treatment of putrescine at a concentration of 1 mM and a foam container with polyethylene film with a value of 6.5 N, which was almost three times the firmness of uncoated fruits. The lowest Physiological Weight Loss, volume, and density were obtained in the same type of coating and packaging. The values of these parameters were 2.458%, 1.82, and 0.833%, respectively, compared to the first day of storage. Overall, the use of polyamine treatment showed a significant effect on changes in the physical properties of persimmon fruit, and foam containers with polyolefin film emerged as the optimal packaging option, resulting in the least amount of change among the different types of packaging used.

Keywords: Loading force, Packaging, Persimmon, Physical properties, Polyamine, Storage

Introduction

Persimmon is a good source of secondary metabolites including antioxidants, carotenoids, and polyphenols, and is a popular fruit in temperate and tropical regions (Veberic *et al*., 2010). Given the popularity of this fruit, it is important to pay special attention to its appearance, as agricultural products are typically subjected to various factors and processes from harvest to consumption. These processes can be simple processes such as cleaning, sorting, washing, moving, and weighing, or they can be complementary or conversion processes that somehow affect the characteristics of the product and sometimes damage the fruit (Azadbakht *et al*., 2019a). If the damage to agricultural products on farms and orchards is added to it, it will cause a large amount of waste in agricultural products. Mechanical damage to crops between harvest

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and consumption is a major factor in declining quality and marketability (Azadbakht *et al.*, 2016; Yurtlu *et al.*, 2005). Therefore, recognizing the different physical, mechanical, chemical, and biological properties and how to maintain or change them in order to achieve the desired goals of the process can have a great impact on maintaining the quantity and quality of the product. Every year, a significant quantity of agricultural and horticultural products goes to waste at various stages, especially after harvest. So that the amount of this waste in third-world countries due to the lack of attention to the principles of storage of agricultural products and lack of development and the evolution of scientific methods of warehousing and damage caused by warehousing pests is more than industrialized countries (Azadbakht *et al.*, 2019b; Azadbakht *et al.*, 2019c). To reduce this wastes, packaging and post-harvest processes can be used. For packaging, it is necessary to know some physical characteristics of fruits. The volume and mass of the fruit are the most significant and easily identifiable physical properties. These factors serve as a basis for various considerations and decisions related to the fruit. Fruits may require containers specially designed for them The volume and surface area of the fruit are useful in predicting the desired amount of drying and therefore in reducing the drying time in the dryer (Azadbakht *et al.*, 2016; Azabakht *et al.*, 2019d). Also, recognizing the characteristics of different types of fruits under different conditions allows us to modify and design machines and industrial processes with new qualitative characteristics, as a result, their losses can be minimized, and operational efficiency can be enhanced. The first step in meeting the quality standards of fruits and improving the different processing lines of these products is to know the different properties of these products and the types of their changes due to various factors (Masoudi *et al.*, 2006). However, the use of coatings to increase the productivity of agricultural products is crucial. These coatings are used to control the rate of product respiration, control physiological diseases and reduce the growth of microorganisms, and most importantly, reduce crop water loss. These coatings are non-toxic substances and a type of wax that is safe for the environment and human health, with no negative effects, which prevents the growth of fungi and maintains the appearance of the fruit for a longer period of time, while they are easy to use (Ardakani *et al.*, 2010). On the other hand, fruit coating in the warehouse may affect the antioxidant capacity and nutritional value of the fruit. In this context, it has been reported that a slight increase in the amount of internal carbon dioxide in the fruit due to the use of coatings increases the synthesis of antioxidant compounds (Jeong et al., 2004). Various studies have been conducted on the effect of coating and packaging factors in different warehouses.

Azadbakht *et al.* (2019e) conducted a study on the effect of loading and storage of pear fruit, which concluded that loading had a significant effect on deteriorating the physical attributes of pear fruit. Mirdehghan *et al.* (2007) conducted a study on the effect of using polyamine coating treatment on pomegranate during storage. The results of this study showed that using this coating in warehousing prevents the reduction of firmness and respiration of pomegranate fruit. Additionally, it has been observed to have an impact on the chemical properties of the fruit. Mirdehghan *et al.* (2016) conducted a study using a coating on grapes, which showed that the application of polyamine treatment during warehousing resulted in lower weight loss compared to control samples and other coatings. Zahedi *et al.* (2018) conducted a study on the effect of polyamine coating treatment on various physical properties of mango. The results demonstrated that the use of this coating during product warehousing delays the rate of water outflow from the fruit, reduces weight loss, and enhances firmness. Cangi *et al.* (2011), examined some physical and chemical properties of kiwifruit at the stage of physiological maturity. They measured the geometric mean diameter, sphericity, specific gravity, the porosity, the area along the three axes Y, X, and Z, and the color properties.

The objective of this study was to examine the physical properties of persimmon fruit under different conditions, as this fruit is known for its sensitivity. In this study, using a quasi-static loading device, the loading force was applied to the product to change the internal tissues. As a result, the physical properties of this fruit, which significantly affect its marketability, undergo rapid changes when subjected to storage conditions. The use of proper packaging and coating for storage of this product increases the durability of this product. This study aimed to investigate the impact of force on persimmons and evaluate the influence of various packaging and coating methods on the rate of change in weight, volume, density, and firmness of persimmons under cold conditions.

Materials and Methods

Sample preparation

In this research, persimmons were obtained from a garden in the Hashemabad region near Gorgan City, Golestan province, Iran. The persimmons were then brought to the laboratory of the Department of Bio-System Mechanical Engineering, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran. Damaged persimmons were separated from the batch, and the remaining spotless persimmons were cleaned with a damp cloth. All persimmons were categorized based on their dimensions, ensuring equalization to minimize experimental errors. Persimmons with extreme dimensions and weight were excluded from the study. After sorting, the remaining persimmons were carefully coated. Subsequently, the coated persimmons were subjected to two levels of load: 150 N and 250 N. They were then packed in foam containers with polyolefin film, polyethylene terephthalate (PET), and ordinary boxes, and stored for 25 days. Then properties such as weight, volume, density, and firmness of persimmons were measured.

Coating

Polyamine putrescine was used for the coating. In the first type of coating, 1 ml of putrescine was applied, while in the second type of coating, 2 ml of putrescine was used. The third type of coating involved the use of distilled water as a control. Additionally, for a comprehensive study, uncoated samples of persimmons were considered as the control group in the experiment. All persimmons were immersed in the coating solution for 10 minutes and then placed on a flat surface in a laboratory at 20°C for drying. To ensure optimal immersion quality, eight persimmons were placed in containers at each stage.

Static loading

Samples of coated persimmons were loaded using a pressure-deformation device (the Santam Indestrone -STM5-Made in Iran) in two pressure load levels: 150 and 250 N. The compression test was conducted using two circular plates, applying a speed of 10 mm per minute. To ensure consistency, all persimmons were loaded in a single direction. Please refer to Fig. 1 for the placement of the samples (Vahedi Torshizi *et al*., 2020).

Packaging and storage

After loading, the samples were packaged using three foil container packs with polyolefin film (Fig. 2.A), polyethylene-terephthalate (Fig. 2.B), and ordinary box (Fig. 2.C). Four persimmons were placed in each pack with polyolefin and polyethylene terephthalate film packaging. After packing, the samples were taken to the cold storage of the Gorgan University of Agricultural Sciences and Natural Resources and placed in a refrigerator at a temperature of 5°C for 25 days.

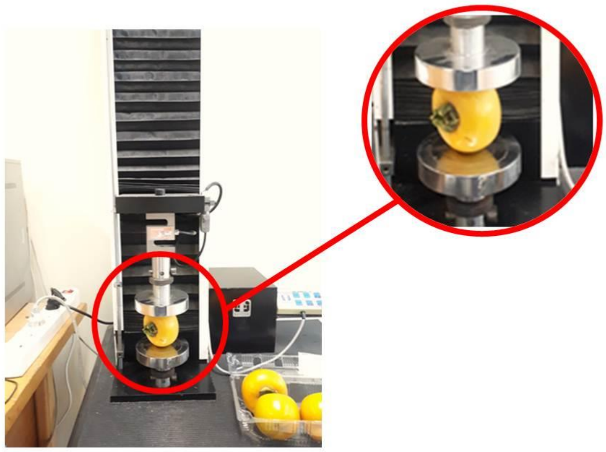

Fig. 1- Loading of persimmons

Fig. 2- Types of packaging used

The physical properties

For physical properties, the weight of each sample was recorded individually and in packages. The package weight was subtracted from the total weight of the samples to obtain the net weight of the individual fruits. The volume of the samples was measured using the water displacement method before coating. The density of each sample was calculated using the appropriate density formula. To determine the package density, the densities of the four fruits placed in each package were summed. The samples' average weight and volume were measured. The packages were then stored in the warehouse for 25 days. After the storage period, the packages were returned to the laboratory, and the weight, volume, and density of each sample and package were re-evaluated. The percentage reduction in weight, volume, and density compared to the initial measurements was calculated. To assess firmness changes, persimmon samples from each package were tested using a penetrometer (EFFEGI model, made in Italy). To conduct this experiment, the skin of the persimmons was protected from damage by applying controlled pressure. Following the provided instructions, the penetrometer probe was positioned on the desired part of the persimmon. By applying the required pressure, the probe penetrated the fruit flesh, and the corresponding value displayed on the penetrometer represented the fruit's firmness (Azadbakht *et al.*, 2019) . The firmness was measured for each sample of persimmon and then an average of 4 persimmons was recorded for each package.

Statistical Analysis

The study focused on investigating the physical properties of persimmons. The independent parameters included loading force at two levels (150 and 250 N), three types of foam container packaging with polyolefin film, polyethylene-terephthalate, and ordinary box, four types of coatings include polyamine with concentrations of 1 and 2 mM, distilled water and non-coated. The dependent factors examined were changes in firmness, weight loss, volume reduction, and density as a percentage during the pre- storage and post-storage stages. All experiments were replicated three times and the results were analyzed using factorial experiments and in a completely randomized design using SAS statistical software and finally, the comparison of means test was plotted on a graph.

Results and Discussion

The results of the analysis of variance for the effects of loading, coating, and packaging factors are shown in Table 1. All three factors showed significant effects on the percentage change in persimmon fruit volume at a statistical significance level of 1%. Additionally, the interaction effects of packaging and coating were found to be significant at a statistical significance level of 5%. Regarding the weight loss percentage, both coating and packaging factors exhibited statistical differences at probability levels of 5% and 1%, while the load force factor and the interaction effects of the factors were not found to be significant. The statistical study of the percentage of density changes indicated that the load force factor has a significant effect on this dependent factor at a 5% level of significance. Furthermore, the coating and packaging factors demonstrated significant effects at a 1% level of significance. No significant effect was observed on the interaction of independent factors regarding the percentage of density changes. Finally, the statistical study of persimmon firmness revealed that all three independent factors- loading force, coating, and packing- significantly affect fruit firmness at a 1% level of significance. Additionally, the interaction effect of loading and coating, as well as the interaction effects of packaging and coating, were found to be significant at a 5% level of significance.

Table 1- Analysis of loading, coating and packaging variance for the parameters of the percentage change in weight, volume, density and firmness of persimmons during storage

	Firmness		**Weight loss percentage**	
	Mean square	**F value**	**Mean square**	**F value**
Loading	13.43	67.70**	0.496	2.52ns
Coating	27.05	133.36**	0.559	2.85*
Packing	28.76	144.94**	13.93	70.78**
Loading × coating	0.677	3.41*	0.004	0.02ns
Loading × packing	0.22	1.12	0.007	0.04ns
Packing × coating	0.532	2.69*	0.044	0.23ns
CV	11.23		19.36	
	Volume loss percentage		Density loss percentage	
Loading	5.58	17.40**	2.75	6.10*
Coating	26.10	81.30**	19.05	42.24**
Packing	29.40	91.60**	6.05	13.41**
Loading × coating	0.078	0.25	0.115	0.25
Loading × packing	0.23	0.72	0.154	0.34
Packing × coating	0.817	2.55*	0.849	1.88
CV	13.61		25.89	

** Significant difference at the statistical level of 1%, * Significant difference at the statistical level of 5%, ns no significant difference

Firmness

The results of the interaction effect of loading force and coating are shown in Fig. 3. Based on the figure, it can be said that increasing the loading force has reduced the firmness of persimmon fruit and in fruits treated with putrescine coating, the amount of reduction has been less than other coatings and the use of putrescine coating has improved the firmness of the samples. The reason for this can be explained by the fact that the use of coating has caused a decrease in the respiration rate of stored fruits, thereby delaying their ripening. When a film or layer of polyamine coating is applied to fruits, it reduces the exchange of ethylene and moisture. This reduction in gas exchange includes a decrease in the infiltration of oxygen and air into the fruit, as well as a decrease in ethylene emission. As a result, the synthesis of ethylene decreases, leading to a reduction in the respiration rate of the fruits and, consequently, a decrease in their ripening process. Meighani *et al.* (2015)on pomegranate (Meighani *et al.*, 2014) and Mirdehghan et al.(2016) on grape (Mirdehghan *et al.*, 2016) who used polyamine coating reported similar results. There was no significant difference in the loading power of 150 N between different concentrations of polyamine, but these concentrations created a significant difference with the coating of distilled and uncoated water. However, the treatment of coating with distilled water and uncoated samplesdid not differ significantly in this force. For the loading force of 250 N, there was a significant difference between all the applied coatings, and the treatment of polyamine with a concentration of 1 mM was able to make a significant difference for the firmness of persimmon fruit. The highest firmness for persimmon fruit was observed in the coating treatment with 1 mM putrescine and the loading force of 150 with a value of 5.91 N and the lowest value was observed in the uncoated state and a loading force of 250 N with a value of 2.36 N. The reason for the changes in the firmness of the fruit with increasing loading can be explained that the force causes changes in the texture and cell wall of the fruit and any change in internal pressure will change the mechanical properties of the cell wall and consequently the whole tissue. In other words, over time and during product storage, by reducing the internal pressure at the cellular level, the stresses caused by mechanical shocks in the product tissue are reduced and as a result, the vulnerability of the product is increased (García *et al.*, 1995).

According to the results obtained for the firmness shown in Fig. 4, the highest amount of fruit firmness was in treatment which used 1 mM of putrescine and for all three packages, the highest value was observed in this coating. For packing foam foil with polyolefine film, polyethylene-terephthalate, and ordinary box, respectively, the highest amount was obtained in 1 mM coating with values of 6.5, 5.6 and 3.95 N. Also, the lowest values were obtained for all three packages in the uncoated state. In the foam container with polyolefin film, a significant difference was obtained between all four coating treatments and for the polyethylene-terephthalate container, no significant difference was observed between the putrescine concentrations. However, the coating of putrescine is significantly different from other coatings, and for the packaging mode with the ordinary box, there was no significant difference in the treatment of putrescine.

There was no significant difference between uncoated and distilled water. Also in the foam container with polyolefin film, persimmon has a limited space compared to other types of packaging, this in itself causes the ethylene content to be lower due to the limited space created and the same controlled space in this package has reduced the amount of ethylene, and this has caused the firmness of the samples in this type of packaging to be higher than other packages. Barmen *et al.* 2011 reported similar results, stated that polyamines maintain the strength of the fruit in their cross-links to the carboxyl group, this is attributed to the cell wall, which strengthens the firmness of the fruit. On the other hand, the use of polyamine binds it to pectin, which blocks and restricts the access of enzymes that destroy cell walls such as pec-methylesterase, pectinesterase, and polygalacturonase, thus lowering the softening speed during storage and Warehousing (Barman *et al.*, 2011). Mirdehghan *et al.* 2007 reported a significant effect of polyamine on pomegranate fruit firmness (Mirdehghan *et al*., 2007).

Physiological Weight Loss

Fig. 5 shows a comparison of persimmon weight loss between packaging and coating. According to the results shown in Fig. 5-A, using foam container with polyolefin film led to lower percentage of weight loss than the other two types of packaging and had a significant difference with the other two packages. In samples containing coating, 1 mM coating resulted in a lower percentage of weight loss than other coatings, and no significant difference was observed between the water coatings and 2 mM polyamine. However, the weight loss percentage of uncoated persimmons differs significantly from other coatings as shown in Fig. 5-B. Fresh fruits lose 3 to 10 percent of their total weight after harvest, and this weight loss in crops may be due to loss of moisture, evaporation, and respiration, which in turn reduces fruit weight (Shiri *et al*., 2013). Also, the loss of fruit weight during storage is due to the exchange of water between indoor and outdoor space, which accelerates the rate of transpiration by cellular degradation, which causes moisture to escape from the samples faster. On the other hand, the loss of water inside the fruit tissue occurs mainly through the cuticle or the physical properties of the fruit or both. For weight loss, the loss of carbon in each respiratory cycle can be considered an important reason for these changes. In fact, the purpose of using coating on the fruit is to prevent the internal moisture of the fruit from evaporating faster (Emamifar *et al*., 2017).

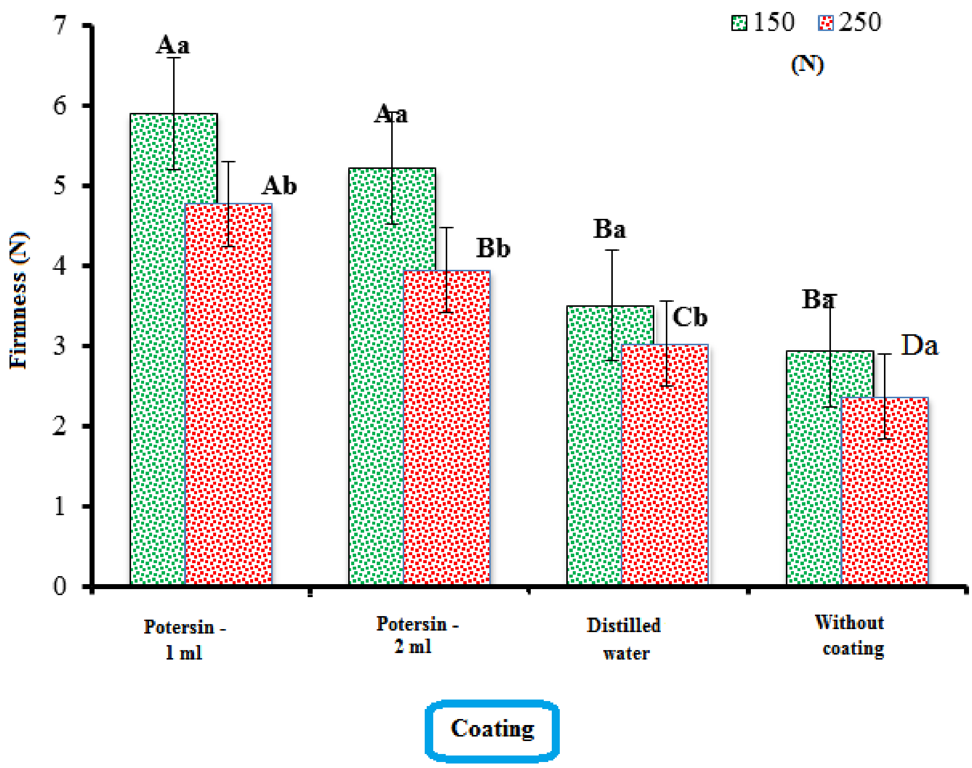

Fig. 3- Interaction of coating and loading on the firm content of persimmon fruit
Large letters similar to no significant difference in a fixed force and small letters similar to no significant difference in a fixed coating

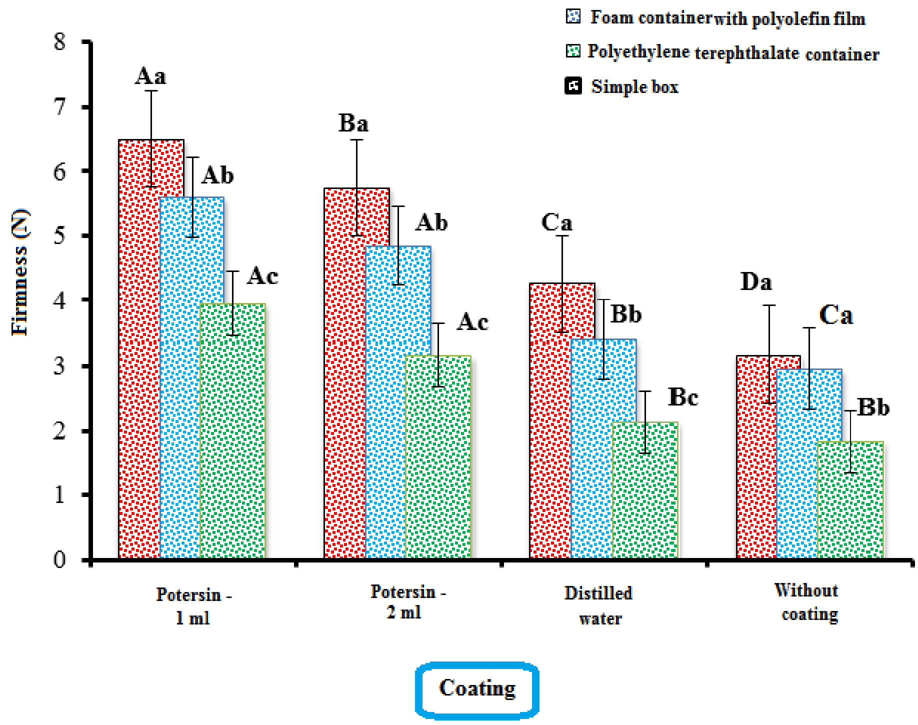

Fig. 4- Interaction of coating and packaging on the firm content of persimmon fruit
Large letters similar to no significant difference in a fixed package and small letters similar to no significant difference in a fixed coating

This is why a significant difference is seen on the use of polyamine coating compared to the control sample. The lowest percentage of weight loss was obtained from foam packaging with polyolefin film with 2.45% and in polyamine coating, 1 mM was obtained with a value of 2.098% and the highest amount was obtained in 4.95 and 4.94%, respectively, in ordinary and uncoated boxes. The results are similar to those of Patel *et al*. (2019) on the effect of coating and storage on pepper (Patel *et al*., 2019) and Champa *et al*. (2014) on grapes with polyamine coating (Champa *et al*., 2014).

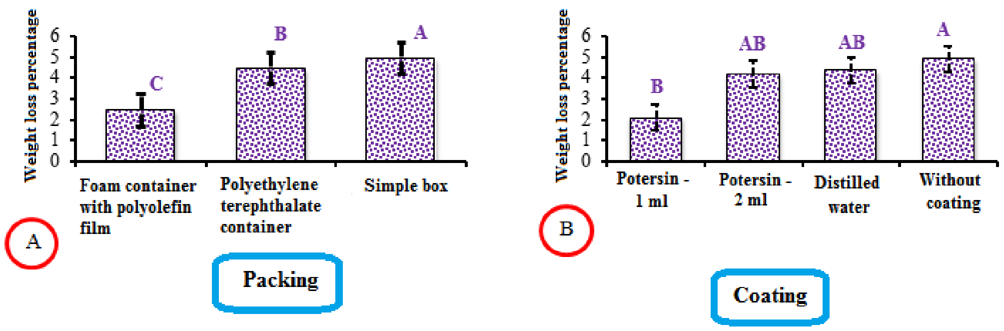

Fig. 5- Comparison of average
A: Packaging B: coating on the percentage of weight loss
The same letters in each part A and B indicate no significant difference

Volume changes

Fig. 6 shows the results of the effect of coating and type of packaging on the percentage change in persimmon fruit volume. Due to the shape of the 1 mM polyamine coating, there is a significant difference between all three boxes. This means that the use of 1 mM polyamine coating caused the number of percentage changes in volume in the type of packaging with "foam container and polyolefin film" to be less. There is no significant difference between this container and the polyethylene-terephthalate container in other coatings. However, the two packages show a significant difference from packing with an ordinary box for the percentage change in persimmon fruit volume. It can be stated that over time, due to environmental factors, moisture is removed and has a direct effect on reducing the volume during storage time (Strik *et al*., 1998). The highest amount of volume changes was observed in the type of packaging of ordinary boxes and non-coated samples with a value of 6.954% and the lowest value was observed with a value of 1.824 in the packaging with foam container with polyolefin film in a 1 mM putrescine coating. Fig. 6-B showed that increasing the loading force had a significant effect on the number of changes in persimmon volume. The reason for this can be stated that by creating pressure and loading, the rate of destruction of the internal structure increases and causes the loss of interstitial water of the product, as a result the volume of the product decreases (Harker *et al*., 1994).

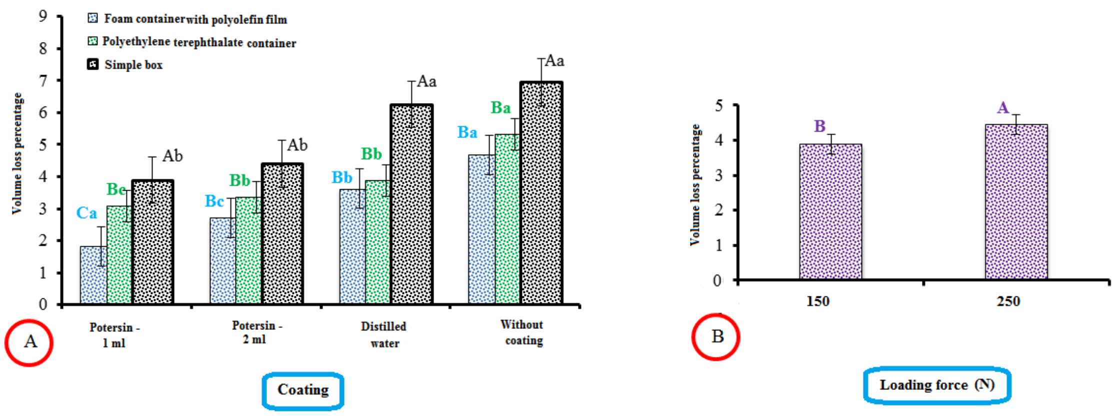

Fig. 6- A: The interaction effect of coating and packaging B: Comparison of the average load force on the percentage of volume changes

Large letters similar to no significant differences in a fixed coating and small letters similar to no significant differences in a fixed package

Density changes

The percentage change in density is shown in Fig. 7. Considering the results presented in Fig. 7-A, the use of polyamine putrescine caused a significant difference compared to other coatings. There was a significant difference between the putrescine concentrations used. The lowest density changes was by1 mM coating used (0.833%) and the highest percentage of density changes was 3.156% in non-coated samples. There was a significant difference between the four coatings applied. Bakhshi *et al*., Who conducted a study on apples in 2011, found a similar result that storage reduced the density of fruits and the reason for this is the destruction of pectin between cells that have spread around after destruction and they are connected to smaller walls, which enlarges the space between the cells (Bakhshi Khaniki *et al*., 2012). Fig. 7-B shows the difference in the type of packaging. The use of foam container packaging with polyolefin and polyethylene films did not differ significantly from each other. However, the percentage of changes in the foam container with polyolefin film was less than the polyethylene-terephthalate container and this amount was 1.44%. However, using an ordinary box had the highest percentage of density changes with a value of 2.43%, which is statistically had significant difference with the other two types of packaging. This might due to the fact that in both types of foam packaging with polyolefin and polyethylene film, the difference in moisture does not exceed one value, and in such a way that persimmons can no longer loss more moisture. This reduces the weight of the specimens and due to the fact that the weight and density have a direct relationship with further weight loss, the density decreased. Fig. 7-C showed the percentage of density changes in different loading forces. Increase in loading force led to increase the rate of density changes with significant difference between the loading forces.

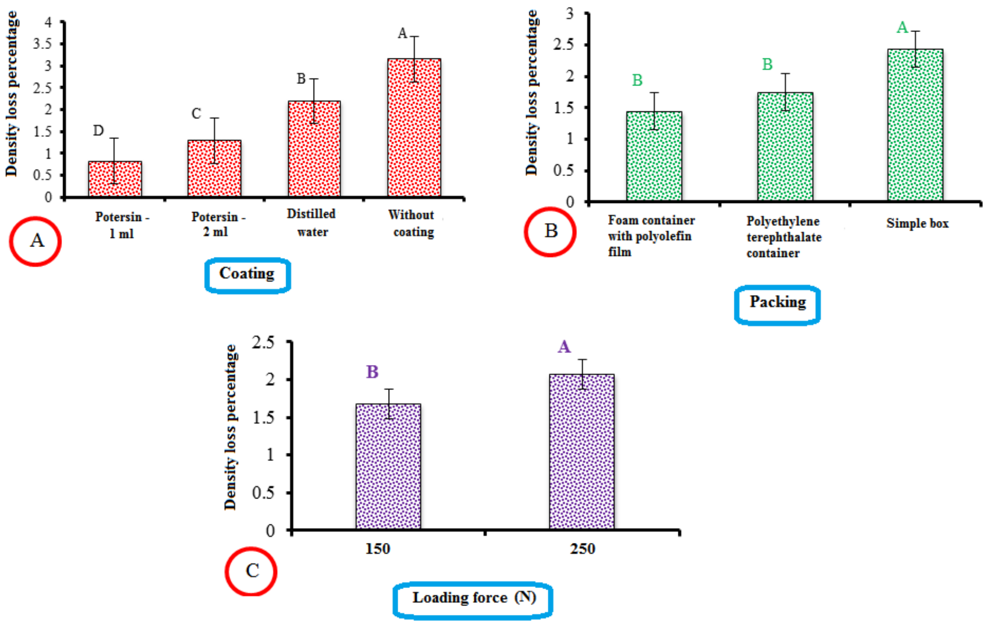

Fig. 7- A: Comparison of mean coating B: Comparison of mean packaging
C: Comparison of Average Load Force on Percentage of Density Changes
The same letters in each part A, B and C mean no significant difference

Conclusion

According to the results obtained from the study of three factors of loading, coating, and packing force, and their impact on the dependent variables of firmness, weight loss percentage, volume, and density, it can be concluded that packaging had a greater influence on firmness and percentage reduction in volume compared to the other two factors. After packaging, coating and loading showed an effect on these variables. In terms of the percentage of density reduction, coating had a more significant impact, followed by independent packing and loading force, which affected the density reduction percentage. Regarding fruit firmness, it was observed that using 1 mM putrescine coating and packaging the fruits with a foam container and polyolefin film resulted in up to twice the rigidity compared to uncoated fruits when using the same packaging. This indicates the effect of coating and the use of this type of packaging, which is observed in both loaded and control fruits. In terms of physiological weight loss, the utilization of equal concentration and packaging density resulted in a twofold decrease in the percentage of changes compared to uncoated sample. For physiological weight loss, the most significant weight changes was observed with the same coating and package in putrescine coating. However, for the percentage decrease in volume, the use of putrescine coating with a concentration of 1 mM and packaging with foam container and polyolefin film resulted in a volume reduction in the samples that was three times lower than the non-coated samples. This highlights the significant impact of this particular packaging and coating. Finally, in terms of the percentage decrease in density, the use of 1 mM of putrescine coating resulted four times fewer density changes than uncoated sample and the use of packaging with foam and polyolefin film reduced the density changes twice compared to the ordinary box. Overall, the use of putrescine coating treatment at a concentration of 1 mM and packaging with foam and polyolefin film can be considered the best coating and packaging for persimmons, regardless of the loading forces.

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تأثیر انواع پوشش و بسته‌بندی بر روی خصوصیات فیزیکی میوه خرمالوی تحت بار

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چکیده

با توجه به اینکه خرمالو یک میوه‌ی حساس به فشار بوده و نگهداری این میوه در انبارها به سختی انجام می‌شود، در این تحقیق سعی شده به بررسی پارامترهای موثر بر کاهش تغییرات خصوصیات فیزیکی آن پرداخته شود. این پارامترها نیروی بارگذاری در ۲ سطح ۱۵۰ و ۲۵۰ نیوتن، سه نوع بسته‌بندی ظرف فومی با فیلم پلی‌اولفین، پلی‌اتیلن ترفتالات و جعبه‌ی معمولی و چهار نوع پوشش پلی آمین پوترسین با غلظت‌های ۱ و ۲ میلی‌مولار، آب مقطر و بدون پوشش بود. خصوصیاتی مانند درصد تغییرات وزن، حجم و چگالی میوه خرمالو و همچنین سفتی این میوه در مرحله‌ی قبل و بعد از انبارداری بررسی شد. با توجه به نتایج بدست آمده برای سفتی میوه‌ها، بیشترین مقدار سفتی در تیمار پوترسین با غلظت ۱ میلی‌مولار و پوشش ظرف فومی با فیلم پلی‌اولفین با مقدار ۶/۵ نیوتن بدست آمد که تقریبا سه برابر سفتی میوه‌های بدون پوشش بود. کمترین میزان درصد کاهش وزن، حجم و چگالی نیز در همین نوع پوشش و بسته‌بندی بدست آمد که مقادیر آن به ترتیب ۲/۴۵۸، ۱/۸۲ و ۰/۸۳۳ ٪ نسب به روز اول انبارداری می‌باشد. در مجموع استفاده از تیمار پلی‌آمین تاثیر مثبتی جهت تغییرات خصوصیات فیزیکی میوه‌ی خرمالو را نشان داد و بهترین ظرف نوع بسته‌بندی که کمترین تغییرات را ایجاد کرد ظروف فومی با فیلم پلی‌اولفین بود.

واژه‌های کلیدی: انبارداری، بارگذاری، بسته‌بندی، پلی‌آمین، خرمالو، خواص فیزیکی

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