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## Full Research Paper

# Effects of various coatings and packing materials on persimmon fruit color indexes during quasi-static loading

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**Abstract**

Nowadays, the quality of processed fruits or products is defined by a set of physical and chemical properties. In this study, due to the sensitivity of persimmon fruit to pressure, the parameters affecting the color changes of this fruit after pressure have been investigated. Three different coatings and packing materials and two loading were applied to study the color changes of the samples. Samples were stored in the refrigerator for 25 days. According to the results obtained for the value of L*, b*, Chroma index, Hue index and color changes, the use of 1 mM polyamine coating had a significant effect and caused less change than other coatings. Foil container packaging with polyolefin film has also been better packaged. The lowest percentage reduction for L*, a*, b* , Chroma index and Hue index values was obtained in the 1 mM polyamine with a value of 8.26%, -26.43%, 12.35%, 1.31% and 120.995% respectively, Also the highest value was obtained in the uncoated state with a value of 18.49%, 73.32%, 19.84%, 15.95%, 152.36%. Finally, polyamine coating treatment has a positive effect to prevent the percentage reduction of color parameters of samples. The best coating treatment was polyamine with a concentration of 1 mM.

**Keywords:** Persimmon fruit, Color changes, Putrescine, Foam containers, Loading.

## Introduction

About the appearance of persimmon fruits, it can be said that their color varies from orange and light yellow to dark orange and red and their diameter, depending on, their variety is between 2 to 8 cm. Usually the flower bowl remains with the fruit after picking. The shape of the persimmon fruit, based on its variety, may be spherical or oak-like (Jing et al., 2013). There are more than 400 varieties of persimmon fruits in various colors and shapes. Due to the fact that there are many varieties of this fruit, it is divided into two categories: astringent and non-astringent (Telis et al., 2002). On the other hand, the quality of fruits or processed fruit products is defined by a set of physical and chemical properties and makes its use more attractive to the consumer, such as size, weight, shape, color, etc. Therefore, it is necessary to pay more attention to the quality of the fruits. Fresh fruits and vegetables that are mechanically damaged during harvesting, transportation, sorting, grading, and packaging need to be investigated. There are also some bruises on fruits that the size of the bruises depends on several factors such as maturity,

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harvest date, temperature, irrigation, and climatic conditions (Stropek and Gołacki, 2015). Due to mechanical damage and the transportation of products and fruits in recent years, there has been a great interest in developing active food packaging. Active packaging can improve food safety and maintain food quality by controlling the environment in the packaging (Wang et al., 2015). Various researchers have done research on the effect of packaging and coating on color changes in agricultural products. Wijewardane et al. investigated the effect of pre-cooling, fruit coating and packaging on post-harvest quality of apple fruit. Their results showed that a concentration of 1.5 to 2% of neem oil as a surface coating along with pre-cooling, in addition to maintaining better physiological properties, significantly reduced the pathogenic microorganisms level on the fruit (Wijewardane and Guleria, 2013). Hazrati et al. evaluated the aloe vera gel as an alternative edible coating for peach fruits during cold storage period. The result showed that the amount of weight loss, color change, total soluble solids (TSS) and titratable acidity (TA) in coated fruit was lower than control (Hazrati et al., 2007). Abebe et al. studied the effects of edible coating materials and stage of maturity at harvest time on storage life and quality of tomato (*lycopersicon esculentum* mill.) fruits. They reported that color is a very important indicator of ripening and determinant of quality and consumer acceptability. The total color difference (ΔE) extensively used to determine ripening due to chlorophyll degradation and formation of lycopene, also coated fruits showed significant delay on change of color as compared to uncoated ones (Abebe et al., 2017).

One of the most important problems of persimmon fruit is its maintenance and sensitivity to compressive strength. It may suffer internal damage during transportation and storage, and its storage life and quality properties may be reduced. Therefore, the aim of this study was to investigate the effect of compressive loading forces and also the type of packaging and coating to increase the durability of this product, in order to provide suitable conditions which increase the quality of persimmon fruit after natural damage and keep it in the best possible condition.

## Materials and methods

### Sample preparation

Persimmon fruits were obtained from a garden in the Hashemabad region near Gorgan city, Golestan province, Iran. All the required persimmon fruits were then brought to the laboratory of the Department of bio-system mechanical engineering, Gorgan, Iran. At this stage, the persimmon fruits that were exposed to external damage were separated. After separating the flawless persimmon fruits in appearance and cleaning them with a damp cloth, all persimmon fruits were categorized in terms of dimensions so that by equalizing the persimmon fruits in terms of dimensions and weight, the error rate of the experiment could be reduced. The persimmon fruits, which were very large and very small, were removed from the samples to be examined. After sorting the persimmon fruits, they were all covered, and then the persimmon fruits covered at two levels of 150 and 250 N were placed under the load. They were then packed in foam containers with polyolefin film, polyethylene terephthalate, and an ordinary box and stored for 25 days. Then, the color parameters of persimmon fruit including L*, a* and b*, browning index, Chroma index, Hue index and color change index were examined as a percentage of changes in the pre- and post-storage stage as a dependent factor. The persimmon fruit moisture content was 75.21% wb.

### Coating

Four types of coating were used in this study, first and second coatings were Polyamine putrescine in different concentrations and third coating was distilled water, then the fruit without any coating that called zero coating was used as control. For the first type of coating, 1 ml of putrescine was used and in the second type of coating, 2 ml of putrescine was used and the third type of coating was distilled water. Also, for better study, the samples of persimmon fruits that were uncoated were considered as control. All persimmon fruits were immersed for 10 minutes and then placed on a flat surface in a laboratory at 20°C to drying. At each stage, 8 persimmon fruits were placed in buckets to achieve the best quality in terms of immersion.

**Static loading**

Samples of coated persimmon fruits were loaded using the Instron device in two load values of 150 and 250 N. Two circular plates were used for the compression test and the test was performed at a speed of 10 mm per minute. To reduce the error, all loadings were done in one direction for all persimmon fruits. Figure 1-d shows the placement of the samples (Vahedi Torshizi and Azadbakht, 2020).

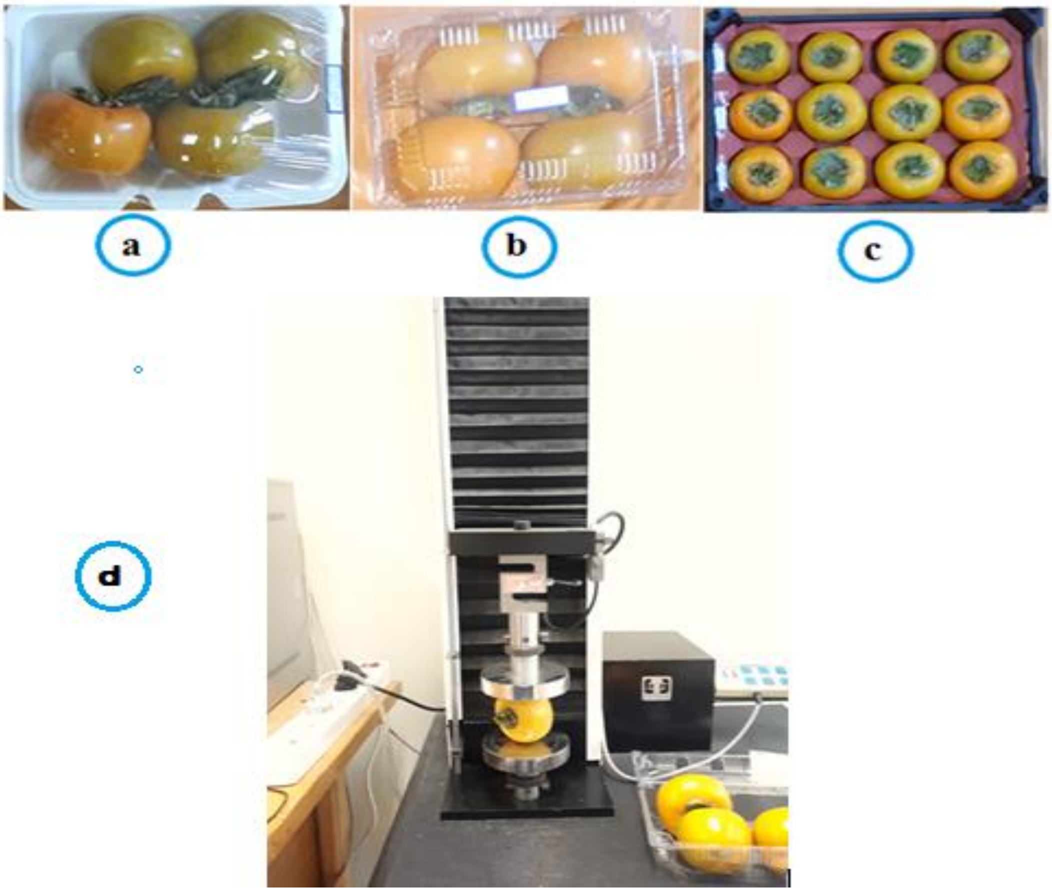


**Fig. 1. Types of packaging used a) Foil container packs with polyolefin film, b) Polyethylene terephthalate, c) Ordinary box, d) Loading of persimmon fruits**

**Packaging and storage**

After loading, the samples were packed using three foil container packs with polyolefin film (Fig.1.a), polyethylene terephthalate (Fig.1.b), and ordinary box (Fig.1.c). Four persimmon fruits were placed in 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.

**Image processing**

Images of all persimmon fruits were first taken after coating and before loading and storage, using Image J software, which is a powerful image processing software. To do this, images of each persimmon in the intended packaging were transferred to image J software.

Considering that 4 persimmon fruits were considered for each package, all four persimmon fruits were analyzed and an average of 4 persimmon were considered for L* a* b*. Also, in this study, all cases are expressed as a percentage so that the errors created can be reduced. In order to study the color indicators, the color space L* a* b* was used. In this space, the L* component indicates the brightness of the persimmon samples, which varies from 0 to 100. If the index goes to zero, the persimmon samples will be darker, and if it goes to 100, the persimmon sample will be lighter. The a* component is also composed of two colors, red and green, and is between 120 and 120+, with positive values indicating more redness and negative values indicating more green in the samples. The values of b* are the same as the components of a*, and the negative values indicate more blue and the positive values are equivalent to yellow.

Samples were photographed in a photo box using the Canon Ixus 132. All photos were saved in high quality as JPEG format. Then, the initial corrections were made to the images, and the images were converted to L* a* b* using the Image J software and the program under Image J, called Convert Color-Space, which is called the program add-on. In the analysis of color values, the values of L, a, and b were used and the reason for this was the independence of this analysis from the device and it covered a wider range than RGB and CMYK. First, pre-processing was performed to improve the images and eliminate unnecessary components in the image for all images. In image processing, the overall goal at this stage is to identify features of the image that can be used for their intended use. Images were converted from RGB color space to XYZ and then to L*, a* and b* using two steps. Using Equations 1, images can be converted from RGB color space to XYZ color space. Using equations 1 to 4, XYZ images can also be converted to L*, a* and b* values (Cheng et al., 2001).

$$\begin{bmatrix}\hat{X}\\ \hat{Y}\\ \hat{Z}\end{bmatrix} = \begin{pmatrix} 0412456 & 0.257580 & 0.180423 \\ 0212671 & 0.715160 & 0.072169 \\ 0.019334 & 0.119194 & 0.950227 \end{pmatrix} \begin{bmatrix}\hat{R}\\ \hat{G}\\ \hat{B}\end{bmatrix} \quad (1)$$

$$\hat{L} = \begin{vmatrix} 116 \times \left(\frac{\hat{Y}}{Y'}\right)^{\frac{1}{3}} - 16 \\ 903.3 \times \left(\frac{\hat{Y}}{Y'}\right) \text{ELSE} \end{vmatrix} \quad (2)$$

$$\hat{a} = 500 \times \left| \left(\frac{\hat{X}}{X'}\right)^{\frac{1}{3}} - \left(\frac{\hat{Y}}{Y'}\right)^{\frac{1}{3}} \right| \quad (3)$$

$$\hat{b} = 200 \times \left| \left(\frac{\hat{Z}}{Z'}\right)^{\frac{1}{3}} - \left(\frac{\hat{Y}}{Y'}\right)^{\frac{1}{3}} \right| \quad (4)$$

$R^*$= The amount of redness.
$G^*$= The amount of greenness.
$B^*$= The amount of blueness.
L*= Indicates the intensity of the light.
$a^*$= The position is between green and red.
$b^*$= The position is between blue and yellow.

There are a number of CIE spaces that can be created once the X> Z tristimulus coordinates are known. CIE ($L^*a^*b^*$) space and CIE ($L^*u^*v^*$) space are two typical examples. They can all be obtained through nonlinear transformations of X, Y, and Z values.

Where, frac Y/ $Y_0$> 0.01, X/ $X_0$> 0.01, and Z/ $Z_0$> 0.01. ($X_0$, $Y_0$, $Z_0$) are X, Y, Z values for the standard white.

Where the values of x ', Y' and Z 'are XYZ values for standard D65.

$$\begin{bmatrix}\hat{X}\\ \hat{Y}\\ \hat{Z}\end{bmatrix} = \begin{pmatrix} 95.047 \\ 100 \\ 108.883 \end{pmatrix} \quad (5)$$

Also, the browning index (BI) was obtained based on the color components and was calculated using Equations 6 and 7 (Moreno et al., 2016):

$$x = \frac{a * +1.75 \times\times L *}{5.645L * +a * -3.012b *} \quad (6)$$

$$BI = \frac{(100(x - 0.33))}{0.17} \quad (7)$$

The measurement of Chroma index and total color difference to describe color changes during persimmon storage under different conditions are shown in equations 8 and 9

(Abdelmotaleb et al., 2009; Montazer and Niakousari, 2012).

$$C = \sqrt{a^{*2} + b^{*2}} \quad (8)$$

$$TCD = \sqrt{(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2} \quad (9)$$

TCD= Colour difference

Zero-sub-indexes are related to the values read from a fresh and non-processed persimmon sample.

The Hue Index is a food color indicator that represents 0 or 360 degrees, red, and 90, 180, and 270, respectively, indicating yellow, green, and blue.

$$HueAngel = \tan^{-1}(\frac{b}{a}) \quad (10)$$

**Table 1- Analysis of loading, coating and packaging variance for persimmon fruit color parameters including L*, a* and b*, browning index, Chroma index, Hue index, color change index, and weight loss percentage.**

| | L* | | a* | | b* | |
|---|---|---|---|---|---|---|
| | **Mean Square** | **F value** | **Mean Square** | **F value** | **Mean Square** | **F value** |
| **Loading** | 605.63 | 18** | 808.61 | 1.11$^{ns}$ | 329.19 | 5.26* |
| **Coating** | 415.106 | 12.37** | 1500.36 | 2.05* | 228.89 | 3.66* |
| **Packing** | 315.53 | 9.38** | 13199.57 | 0.07** | 341.84 | 5.46* |
| **Loading ×Coating** | 8.10 | 0.24$^{ns}$ | 138.75 | 0.19$^{ns}$ | 2.51 | 0.04$^{ns}$ |
| **Loading× Packing** | 75.107 | 3.20* | 89.26 | 0.12$^{ns}$ | 2.18 | 0.31$^{ns}$ |
| **Coating× Packing** | 3.94 | 0.12$^{ns}$ | 1236.06 | 1.69$^{ns}$ | 14.85 | 0.24$^{ns}$ |
| **C.V.** | 14.90 | 33.64 | 35.97 | 730.61 | 19.92 | 62.57 |
| | **Browning index** | | **Chroma index** | | **Hugh's Index** | |
| **Loading** | 612.50 | 1.47$^{ns}$ | 525.20 | 9.96** | 2267.66 | 4.69* |
| **Coating** | 679.66 | 1.63$^{ns}$ | 188.04 | 3.57* | 1989.87 | 4.12* |
| **Packing** | 11.70 | 0.03$^{ns}$ | 1571.42 | 80.29** | 12639.24 | 26.16** |
| **Loading ×Coating** | 265.25 | 0.64$^{ns}$ | 7.53 | 0.14$^{ns}$ | 33.97 | 0.07$^{ns}$ |
| **Loading ×Packing** | 1611.99 | 1.04$^{ns}$ | 38.74 | 0.73$^{ns}$ | 30.91 | 0.06$^{ns}$ |
| **Coating× Packing** | 85.70 | 0.21$^{ns}$ | 11.25 | 0.21$^{ns}$ | 809.24 | 1.67$^{ns}$ |
| **C.V.** | 27.44 | 416.95 | 10.81 | 52.73 | 16.11 | 483.46 |
| | **Total color change index** | | | | | |
| **Loading** | 91.83 | 3.01$^{ns}$ | | | | |
| **Coating** | 100.06 | 3.28* | | | | |
| **Packing** | 2.004 | 0.07$^{ns}$ | | | | |
| **Loading ×Coating** | 2.42 | 0.08$^{ns}$ | | | | |
| **Loading ×Packing** | 34.84 | 1.14$^{ns}$ | | | | |
| **Coating× Packing** | 13.41 | 0.44$^{ns}$ | | | | |
| **C.V.** | 29.82 | 30.54 | | | | |

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

**Statistical analysis**

Independent parameters in this study include loading force at 2 levels of 150 and 250 N, three types of foam container packaging with polyolefin film, polyethylene terephthalate and ordinary box and four types of polyamine coating with concentrations of 1 and 2 mM, distilled water and without coating. The color parameters of persimmon fruit, including L*, a* and b*, browning index, Chroma index, Hue index and color change index, were examined as a percentage of changes in the pre- and post-storage period as a dependent factor. All experiments were performed in three replications, and the results were analyzed using a factorial experiment and in a completely randomized design using SAS statistical software.

## Results and discussion

In Table 1, the results of variance analysis of loading, coating and packaging for persimmon fruit color parameters including L*, a* and b*, browning index, Chroma index, Hue index, color change index, and weight loss percentage are shown.

**Comparison of the average percentage of decrease in the amount of L ***

Figure 2-A shows a comparison of the average percentage of L*. According to the figure, it is observed that there is no difference between distilled and uncoated water and both the concentrations of polyamine are significantly different from each other and compared to the other two coatings. The use of polyolefin coating has reduced the amount of L* value.

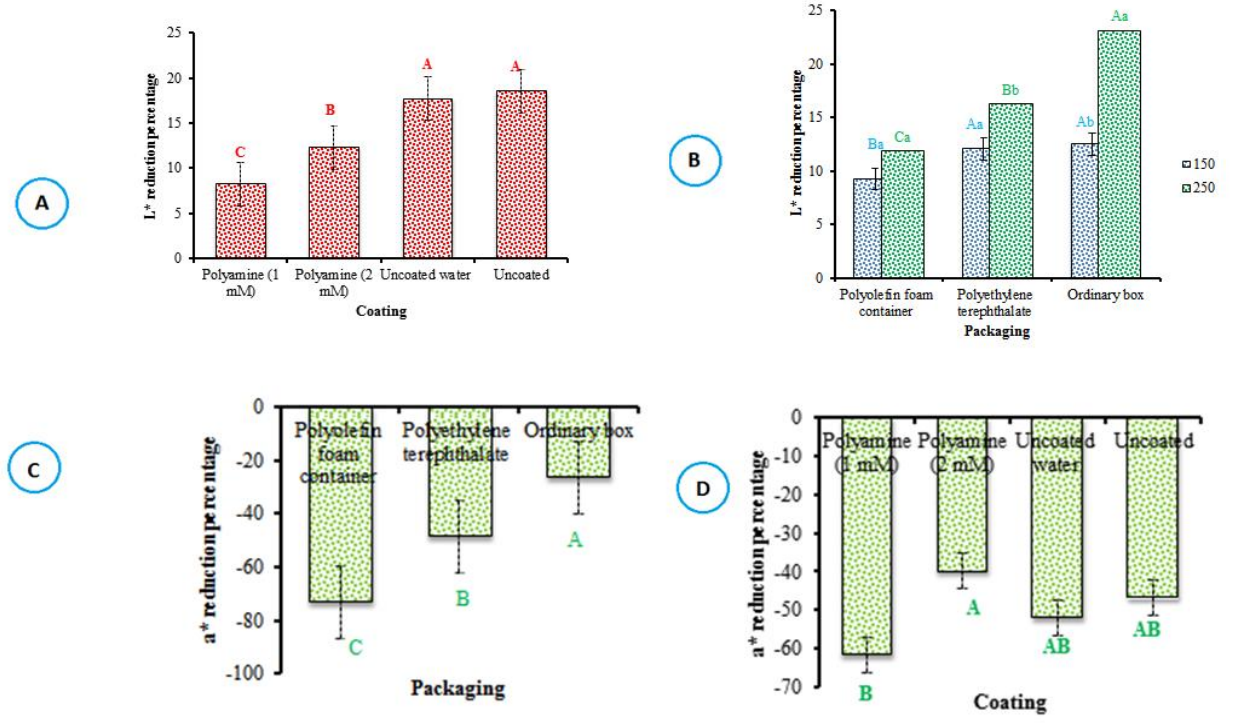


**Fig. 2.Comparing the average for A) amount L* in coating, B) Effect of loading and packing on the amount of L *, C) Amount a* in packing, D) Amount a* in coating,**
The same letters indicate no significant difference.
Large similar letters indicate a significant difference between different packing levels and small similar letters indicate a significant difference between different levels of loading force.

The lowest p reduction ercentage in L* value was obtained in the 1 mM polyamine with a value of 8.26% and the highest value was obtained in the uncoated sample with a value of 18.49%. Due to the stabilization of the membrane, polyamines can maintain the appearance of product and delay their aging during storage. As fruits get closer to aging, they increase the amount of wrinkles and weight loss. Polyamines, on the other hand, are known as anti-aging compounds and have the ability to maintain the integrity of the membrane, so it can be said that fruits treated with polyamines will have less wrinkles and weight loss. Ultimately, this will keep the product looking good and shiny. The low percentage of shrinkage index reduction with the application of coating on the fruit surface in this study is consistent with the results of other study on strawberries (Asghari et al., 2009; Hernandez-Munoz et al., 2008) .

**The interaction effect of loading and packaging on the percentage reduction of L* value**

Figure 2-B shows the results of the interaction of packing materials and loading force on the percentage reduction of L* value. Using the results at 150 N, there was no significant difference between the ordinary box and the polyethylene terephthalate but the polyolefin foam container was significantly different from the other two packages. For the loading force of 250 N, there was a significant difference between all three packages. Also in the ordinary box and polyethylene terephthalate, there was a significant difference between 150 and 250 N, because the more loading force created more damage into fruit texture and this is the reason for the significant difference between the amount of L* in 150 and 250 N. No significant difference was observed for polyolefin film. These results are due to the fact that foam containers, with polyolefin and polyethylene terephthalate films, inhibit the activity of decomposing enzymes and are good barriers to prevent the dehydration of the samples. As a result, due to the lower dehydration in the samples in the mentioned packages, the low level of L* value or fruit brightness was also found. This result is similar to the other results (Hernandez-Munoz et al., 2008; Serrano et al., 2005). Other researchers, by adding different coatings of thymol, menthol and eugenol in the packaging of cherry fruit, delayed the change in skin color and fruit tail relative to the control samples and obtained similar results (Serrano et al., 2005).

**Comparing the average percentage of decrease in the amount of a***

Figure 3-C shows the average comparison for a* coating and packaging. According to Figure 3-C, it can be seen that the value of a* has increased compared to the value of a* on the first day of the samples, and foam containers with polyolefin film have shown the highest decrease value for the value of a*. There is a significant difference between all three types of packaging used.

For coating, the highest percentage increase of a* was 1 mM, and no significant difference was found for coating between distilled and uncoated. But 1 mL of coating was significantly different from other coatings. The lowest percentage increase of a* was obtained in foam packaging with polyolefin film with a value of -26.43% and in polyamine coating of 1 mM with a value of -39.93%. Negativity indicates an increase in the amount of a* compared to the first day, and the highest value is 73.32% and 61.62%, respectively, in foam packaging with polyolefin film and 1 mM polyamine concentration. The reason for this observation is that by increasing storage time the pH of persimmon specimens increases and thus destroys the anthocyanin pigments responsible for the red dyes. This reduces the color of the fruit. Increasing the concentration of the coating also prevents respiration and maintains the levels of organic acids and reduces the pH. Therefore, lowering the pH will prevent the reduction of a*. Also, the use of polyamine has reduced the aging period, and therefore the use of this coating with higher concentration has caused less color changes. This is similar to the results of Jiang and Li (2001).

**Comparison of average percentage reduction of b* value**

The results of the average value of b* for packages, coatings and loading forces are shown in Figure 3. According to Figure 3-a, it can be said that the use of ordinary boxes has increased the amount of b* of persimmon fruits, and of course, there was no significant difference between the packaging of polyethylene terephthalate compared to the other two boxes. However, the foam container covered with polyolefin film makes a significant difference in the b* value compared to the ordinary box. Figure 3-b, which is to compare the average effect of the load force, shows that the increase in load force has made a significant difference for the value of b* and a significant increase for this factor was obtained with increasing load force. Figure 3-c also shows that the use of polyamine coating causes significant changes in the amount of b* compared to other coatings and the use of polyamine coating with a concentration of 1 mM has caused less changes in the amount of b* during storage. There was also no statistically significant difference between distilled water coating and non-coated treatments. The lowest percentage of b* reduction was obtained in foam packaging covered with polyolefin film with 12.35% and in loading force of 150 N with 13.7% and in polyamine coating of 1 mM with 11.23%. The highest values were 19.84%, 17.98 and 19.86, respectively, in the ordinary box, 250 N and uncoated. The reason for these results is that after harvest time and during storage, the color of the fruit changes. An increase in the percentage of reduction the amount of b* in the samples packed in ordinary box can also be due to further dehydration in the samples in this type of packaging due to the lack of inhibitory activity of hydrolyzing enzymes. These results are similar to the results of Hernandez-Munoz et al. (2008). In similar experiments, the addition of a coating to the cherry fruit delayed the discoloration of the skin and tail of the fruit compared to the control samples (Hernandez-Munoz et al., 2008; Serrano et al., 2005).

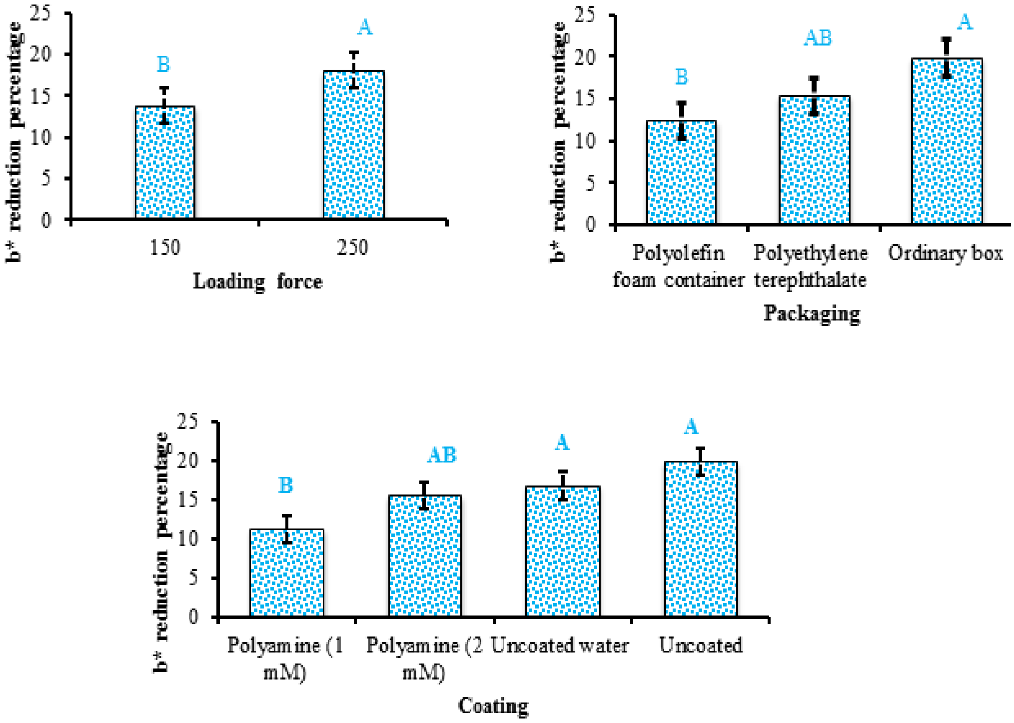


**Fig. 3. Average comparison on b *, a) Packing, b) Loading, c) Coating.**
The same letters indicate no significant difference.

**Comparison of the average percentage reduction of Chroma index**

The results of the mean comparison for the Chroma index for loading force, packaging and coating are shown in Figure 4. According to the results, for the packaging factor, the use of ordinary boxes increases the Chroma index, and there was no significant difference between the packaging of foam containers coated with polyolefin film and polyethylene terephthalate. Figure 4-B shows that an increase in the loading force increases the b* reduction percentage and a significant difference was observed between the loading forces. For coatings, only the use of

1 mM coating has caused a significant difference between the percentage reduction of Chroma index for persimmon fruits and the other three coatings were not significantly different. The lowest percentage reduction of Chroma index was obtained in foam packaging covered with polyolefin film with a value of 1.31% and in loading force of 150 N with a value of 4.22% and in polyamine coating of 1 mM with a value of 2.34%. The highest values were 15.95%, 9.62 and 9.93, respectively, in the normal box, 250 N, and uncoated. The reason for these observations is that the color of the fruit changes over time after harvest and during the storage period. The fruits are darkened, the brightness and clarity of the color of the surface of the fruit decreases. Eventually browning of the fruit surface occurs. The reason for the low percentage of Chroma index reduction in vegetation samples can be due to the prevention of fruit dehydration. Dehydration causes browning of the fruit. In a similar study, the addition of thymol, menthol, and eugenol coatings in cherry delayed skin and fruit color variability compared to the control (Hernandez-Munoz et al., 2008; Serrano et al., 2005). The increase in this index is consistent with the results of research performed on strawberries by applying the coating on the fruit surface (Lester, 2000; Asghari et al., 2009).

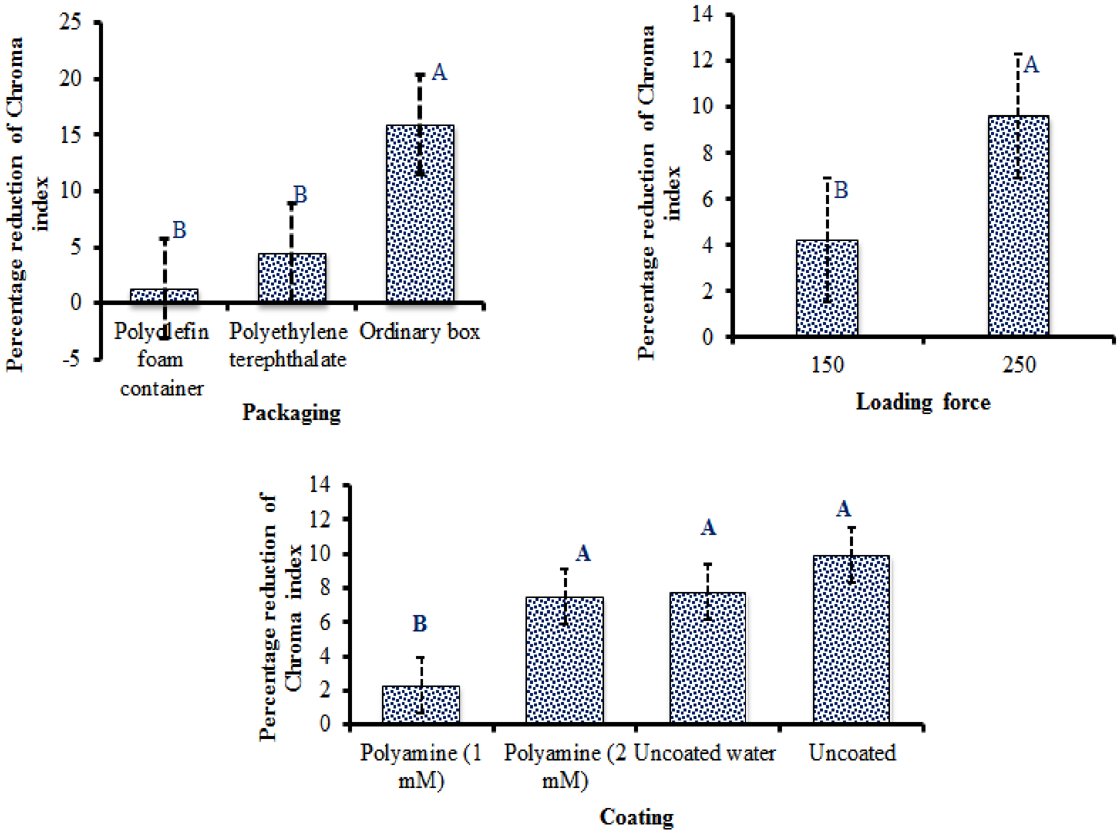


**Fig. 4. Comparison of average on Chroma index value, a) Packaging, b) Loading, c) Coating.**
The same letters indicate no significant difference.

**Comparison of average percentage decrease of Hue index**

Figure 5 shows a comparison of the average percentage of reduction in the Hue index. Section A shows that the foam packages covered with polyolefin and polyethylene terephthalate did not differ significantly. However, the ordinary box with these two types of packaging has shown a significant difference and a significant increase for the percentage reduction of the Hue index. In Figure 5-B, the increase in load force also causes a significant increase in the percentage reduction of the Hue index, and a significant difference was obtained between the two loading forces. It can be seen in Figure 5-C, that the use of 1 mM polyamine treatment has caused a significant difference compared to other coatings for the percentage reduction of Hue index and no significant difference was observed between other coatings. Minimum percentage reduction of Hue index was obtained in foam packaging covered with polyolefin film with 120.995% and in the loading force of 150 N with a value of 130.8% and in the polyamine coating of 1 mM with a value of 120.84%. The highest values were obtained in 144.03, 152.36 and 143.33%, respectively, in a normal box, 250 N and uncoated. The reason for these observations is that coating polyamines on the fruit surface reduces the hydrolytic activity of thylakoid membrane enzymes, thus delaying the decomposition of chlorophyll and the production of carotenoids, as well as reducing discoloration. The color changes and the amount of Hue index in the skin of the fruit during storage were also reduced. Many researchers have also cited this phenomenon as evidence for their laboratory observations (Lester, 2000; Malik and Zora, 2005; Martinez-Romero et al., 2002). In a similar study, Valero et al. (2013) investigated the effect of edible coatings on maintaining fruit quality in four types of plums during storage after harvest and they concluded that discoloration was delayed by using both edible coatings (Valero et al., 2013).

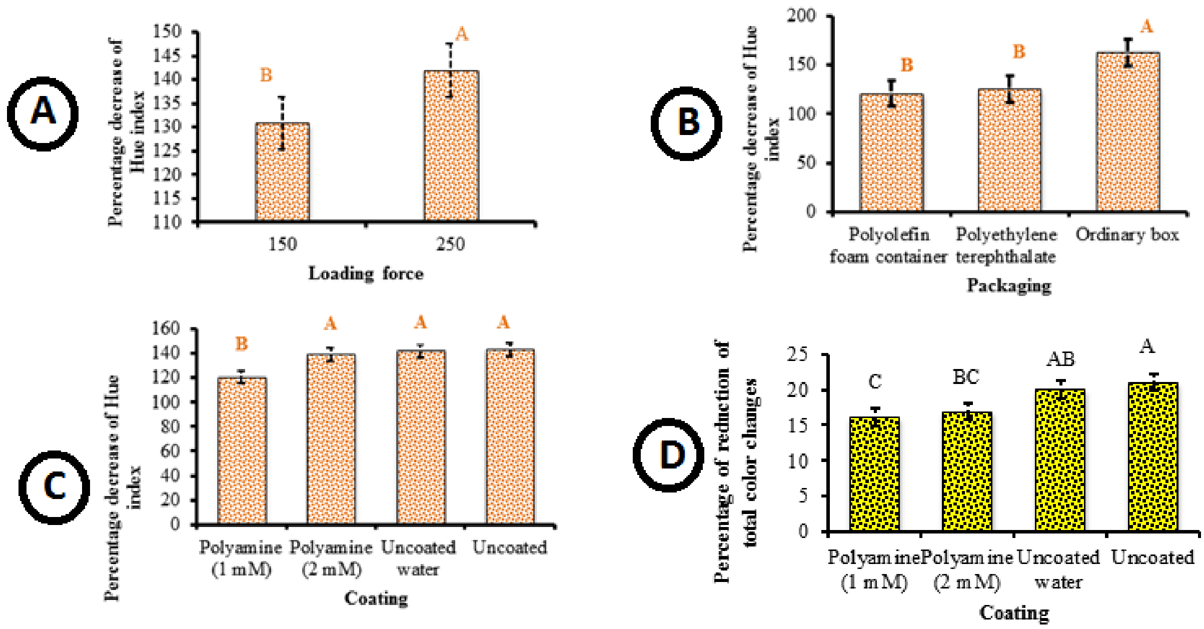


**Fig. 5. Comparison of average on Hue index and total color changes rate, a) Loading, b) Packing, c) Coating, d) Coating.**

The same letters indicate no significant difference.

**Comparing the average percentage of reduction of total color changes**

Figure 5-D shows an average comparison for the percentage reduction in the color of the whole persimmon fruit. According to Figure 5-D, the use of polyamine has caused the percentage reduction in color changes to be significantly different from that of distilled and uncoated samples. The lowest amount was in the 1 mM polyamine coating with a value of 16.33% and the highest amount of color changes was for the un-coated treatment with a value of 21.029%. One of the indicators of fruit ripening is the change in skin color. The color

of a fruit is a very important factor in evaluating its quality. The reason for this result is that increasing the amount of $CO_2$ in the fruit and also reducing the production of ethylene due to coating reduced the rate of respiration and discoloration of the fruit. In similar experiments, delays in discoloration due to the use of coatings have demonstrated in many fruits, including mangoes (Valero et al., 2013), guava (Hong et al., 2012), and plums (Liu et al., 2014). Researchers in a similar study reported that increasing the amount of $CO_2$ in the fruit, as well as reducing ethylene by coating the fruit with chitosan, reduced respiration and discoloration of the fruit (Martínez- Romero et al., 2006).

## Conclusion

Based on the results obtained in general, it can be stated that the use of foam packaging covered with polyolefin film has caused the percentage reduction of L*, b* parameters, Chroma index, and Hue index to be less than other packages. Also, after this packaging, polyethylene terephthalate had the best values. The loading factor for the parameters also showed that when the load force increases, the amount of change of all parameters will be higher than the samples with less pressure. The lowest percentage reduction for L*, a*, b*, Chroma index and Hue index values were obtained in the 1 mM polyamine with a value of 8.26%, -26.43%, 12.35%, 1.31% and 120.995%, respectively, Also the highest value was obtained in the uncoated tratment with a value of 18.49%, 73.32%, 19.84%, 15.95%, 152.36%. Finally, polyamine coating treatment has a positive effect to prevent the percentage reduction of color parameters of samples. The best coating treatment was polyamine with a concentration of 1 mM.

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# تاثیر پوشش و بسته‌بندی مختلف بر روی تغییرات شاخص رنگ میوه خرمالو در بارگذاری شبیه استاتیکی

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## چکیده

امروزه، کیفیت میوه‌ها و یا محصولات فراوری شده توسط مجموعه‌ای از خصوصیات فیزیکی و شیمیایی تعریف می‌شود. در این تحقیق، با توجه به حساسیت میوه خرمالو به فشار، به بررسی پارامترهای موثر بر تغییرات رنگی میوه پرداخته شده است. بر روی نمونه‌ها سه پوشش مختلف شامل پوترسین با غلظت ۱ میلی مولار، پوترسین با غلظت ۲ میلی‌مولار و آب مقطر بر روی آن‌ها قرار گرفت. سپس نمونه‌ها تحت نیروی بارگذاری ۱۵۰ و ۲۵۰ نیوتن قرار گرفته و در ظروف فومی با فیلم پلی‌اولفین، پلی‌اتیلن ترفتالات و جعبه معمولی بسته‌بندی شدند. نمونه‌ها به مدت ۲۵ روز در سردخانه انبار شدند. پس از اتمام دوره انبارمانی، خواص کیفی نمونه‌ها شامل مقادیر L*، a*، b*، شاخص قهوه‌ای شدن، شاخص کروما، شاخص هیو و شاخص تغییرات رنگ کل اندازه‌گیری شد. با توجه به نتایج به‌دست آمده برای مقدار L*، b*، شاخص کروما، شاخص هیو و تغییرات رنگ استفاده از پوشش ۱ میلی‌مولار پلی‌آمین تاثیر معنی‌داری داشته است و سبب تغییرات کمتر نسبت به پوشش‌های دیگر شده است. بسته‌بندی ظرف فومی با فیلم پلی‌اولفین نیز بهتر بسته‌بندی بوده است. کمترین درصد کاهش برای مقادیر L*، a*، b*، شاخص کروما و شاخص Hue در پلی‌آمین ۱ میلی‌مولار به‌ترتیب با مقادیر ۸/۲۶٪، ۲۶/۴۳-، ۱۲/۳۵، ۱/۳۱٪ و ۱۲۰/۹۹۵٪ به‌دست آمد. بیشترین مقدار در حالت بدون پوشش با مقادیر ۱۸/۴۹٪، ۷۳/۳۲٪، ۱۹/۸۴٪، ۱۵/۹۵٪، ۱۵۲/۳۶٪ به‌دست آمد. در نهایت تیمار پوشش پلی‌آمین تاثیر مثبتی در جلوگیری از درصد کاهش پارامترهای رنگی نمونه‌ها دارد. بهترین تیمار پوشش پلی‌آمین با غلظت ۱ میلی‌مولار بود.

**واژه‌های کلیدی**: خرمالو، تغییرات رنگ، پوشش‌دهی، بسته‌بندی، بارگذاری.

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