The antioxidant properties of compressed persimmon fruit using putrescine coatings and polyamine films

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Abstract: This study was conducted considering the high importance of persimmon's chemical properties and the effect of different factors on its variations during storage and maintaining period. This study attempted to investigate some cases such as the effect of compressive loading parameters at 2 levels of 150 N and 250 N, three types of foam container packaging with polyolefin film, polyethylene terephthalate, and ordinary box and four types of putrescine polyamine coating with concentrations of 1 mM and 2 mM, distilled water and uncoated state, the chemical properties of persimmon fruit including the number of antioxidants, total phenol, flavonoids, vitamin C, pH, acidity and dissolved solids. The results showed that the highest content of total phenol and flavonoids was observed in 1 mM putrescine coating and foam container packaging with polyolefin film equal to 109.13 and 6.851 µMQ / 100Gfw and the highest amount of flavonoids and solids in 150 N and 250 N load was equal to 6.97 QMQ / 100Gfw and 19.94 QMQ / 100Gfw, respectively. The highest amount of antioxidants was observed in the foam container with polyolefin film, 1 mM coating and loading force of 150 N. Also, the highest amount of vitamin C was in the coating part for 1 mM putrescine coating with the amount of 14.36 mg / 100gFW and the packaging part in the packaging with foam containers using polyolefin film with the amount of 13.7 mg / 100gFW and the highest value also appeared in the coating treatment with distilled water and 250 N load with the value of 6.83 mg / 100 gFW. In reviewing the pH value, the highest pH value was subject to the uncoated samples and the loading forces of 250 N. It was generally stated that the foam container with polyolefin film and 1 mM putrescine coating created the best values to maintain the qualitative properties.

Keywords: persimmon, coating, packaging, antioxidant, vitamin C

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1 Introduction

Persimmon, belonging to the Ebenaceae family, was eaten as fresh fruit and useful for many diseases. The fruit is frequently consumed fresh but could be used frozen, canned, or dried. Additionally, this fruit could be stored in a modified or controlled area for up to 6 months. According to its consumption, dried pieces of persimmon were benefited as a substance in products such as snacks and breakfast cereals (Doymaz, 2012). Also, Persimmon was considered as a seasonal fruit with notable health benefits. Using persimmons in the production of wine and sweets was examined and used by molecular methods for

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the discerning yeast bacteria and Acetic Acid Bacteria (AAB) isolated from alcoholic fermentation and recognition of fruit. This fruit was known as a good source of bioactive compounds such as ascorbic acid, compressed tannins, and carotenoids and was found beneficial for health due to its antioxidant properties (Plaza et al., 2012). Persimmon contained pro-anthocyanidins along with antioxidant, anti-inflammatory, and anti-atherosclerotic activity (Li et al., 2010). Persimmon, as a good source of primary metabolites (especially sugar-rich) and many dietary antioxidants, carotenoids, and polyphenols, was noticed as a kind of well-known fruit in temperate and tropical regions. Persimmon was mostly eaten fruit in Europe (Butt et al., 2015). One of the reasons for its consumption was the considerable amount of sugar in the fruit and the moderate concentration of organic acids, subscribing significantly to the body's sensory characteristics. The ratio of sugar to organic acids and the unique sugar content were directly associated with the fruit's sweetness and aroma sensations. Glucose, fructose, and sucrose were responsible for creating a fragrant taste in fruits, all of which changed during storage and packaging. The issue of storage and packaging was noticeable in preventing fruit changes (Veberic et al., 2010).

The storage and packaging of fruits (seasonal fruits) for a long time was of utmost significance to maintain the necessary quality and aid usage throughout the year. The health and safety of the populace have been significantly considered as major issues in recent decades (Kalia and Parshad, 2015) Because the safety and quality assurance of packaged fruits and fruit products have led to a major concern in food supply chains throughout today's world (Kalia and Parshad, 2015). A wide range of packaging materials and molds was produced in the food industry. It was profited as processed for offices, storage in warehouses, and distribution in the market from harvest to consumption. Different materials such as glass, plastic, metal, cardboard were used in the manufacture of packaging containers that reported by Gospodinov et al. (2011) and Bronlund et al. (2014) for corrugated packaging and Lufu et al. (2020) plastic packing and finally Arapitsas et al. (2020) for glass bottle. The useable materials were reliant on the nature of the food product because the packaged materials were attended with a wide range of functional properties that were efficient at shelf life. Often, bottles and glass vessels were applied to package liquid food, while solid food products were mostly packaged in plastic and cardboard.

On the other side, fruit coating in the warehouse might be functional in the amount of antioxidant capacity and nutritional value of fruits. In this context, it was reported that a slight increase in the amount of internal carbon dioxide in the fruit, raised by the application of coatings, led to an increase in the synthesis of compounds with antioxidant properties (Jeong et al., 2004). In the review of the effect of *Citrus reticulata* cultivar Unsho, it was realized that coating caused a reduction in the rate of respiration. It was also significantly effective in preserving dissolved solids, acidity, and vitamin C (Jemriić and Pavičić, 2004). The studies conducted by Chien et al. (2007) indicated that the treatment of citrus fruits using chitosan was instrumental in controlling fungal rot during storage. Ardakani et al. (2010) examined the effect of chitosan on increasing post-harvest shelf life and maintaining the quality of the *Shahroudi* cultivar. They concluded that chitosan reduced the rate of weight loss, cracking, browning, spoilage, and shedding of berries and increased their quality (Ardakani et al., 2010). Navgaran et al. (2014) carried out a test on cherry storage and inferred that cherry antioxidants' value would diminish through increasing storage period (Navgaran et al., 2014). The other test was attempted on examining the effect of the shelf-life period, and loading force on the total phenolic content, acidity, and sugar in apples, and the researchers declared that increasing the shelf life period minimized the amount of acidity, sugar and phenolic content (Ziaratban et al., 2018). Moreover, numerous researches were done on the packaging and coating of the fruits.

Erbaš et al. (2018) studied the effect of pre- and post-harvest treatments of spermidine on the shelf life and quality of apricot cultivar of apricot fruit, indicating an increase in the weight loss of all coated and uncoated fruits during storage time. The coated fruit represented the least weight loss after harvesting in comparison with other treatments. The control groups exhibited the highest value of brownness inside the fruit at the end of the storage period. Regarding the results extracted from sensory evaluation, coated apricot was stored with a dose of 0.1 mg of spermidine in MAP conditions for 30 days (Erbaš et al., 2018).

Hosseini et al. (2018a) researched the effect of post-harvest chitosan treatments and putrescine to save the quality and increase the shelf life of two banana cultivars. In this study, weight loss, microbial population formation, and decreased total dissolved solids, ethylene production, ascorbic acid content, and fruit lightness were gradually evident in the control group during the storage period. All of these changes were significantly slowed down after contact with chitosan and putrescine. Making use of these coatings eventuated to a quantitative increase in the phenolic compounds content and antioxidant activity during storage. The obtained results indicated that a coating with 1% chitosan was found effective in improving the quality and shelf life of bananas after harvest. There was also the possibility of effective chitosan in low concentrations (Hosseini et al., 2018a).

Abbasi et al. (2019) investigated the effect of putrescine coating on peach during the storage period. The results indicated that using putrescine spray significantly reduced the CI amount and minimized the fruit's softening. Without regarding the different doses or the consumption time, a reduction appeared in the fruit weight, dissolved solids, titratable acidity, and fading of skin color (AsA) in the storage period. However, it imposed positive effects on the qualitative properties of peach, including CI, which was more diagnosed at higher doses of putrescine, especially when using 2 mM putrescine. Correspondingly, the CI in peach fruit was probably mixed with considerable amounts of 1 mM to 3 mM putrescines during the growing period and could be stored at low temperatures for up to 6 weeks without any impact on the quality of the peach (Abbasi et al., 2019).

Respecting the high significance of antioxidant chemical properties for fruits and the positive effect of this type of properties on human health, as well as many variations in these properties during different environmental stresses and the negative effect on these cases, this paper was aimed at studying the effect of coating and different types of packaging on chemical properties variations of persimmon during storage period.

2 Materials and methods

2.1 Sample preparation

In this study, persimmons were prepared from a garden in Hashemabad region around Gorgan city, Golestan province, Iran and later transferred to the laboratory of Mechanical Biosystems Department, Gorgan University after harvesting where the persimmons with apparent damage were sorted out and discarded while the good persimmons based on appearance were cleaned with a moist tissue and classified thereafter in terms of dimensions and weight to reduce the amount of error in the test. The very large and very small persimmons were exempted from the test and the mean for length, width and thickness of persimmon were 72.855, 71.62, 48.64 respectively. After ordering, all of the persimmons were coated. Then the coated persimmons were loaded in two levels of 150 N and 250 N, they were assigned in foam containers with polyolefin film, polyethylene terephthalate, and ordinary box and were stored for 25 days. In the following, the tested samples were prepared with the purpose of measuring the chemical properties.

2.2 Coating

Putrescine polyamine was used for coating and the concentration was 1 Millimolar 2 mM, respectively, and distilled water was used in the third type of coating. Moreover, for better investigation of persimmon samples without coating, it was regarded to define this state as the fourth type of coating in the test. To dry all persimmons, they were immersed for 10 minutes and then placed on a flat surface in a laboratory environment at 20 ℃. At each phase, 8 persimmons were placed in buckets to derive the best quality in terms of immersion.

2.3 Static loading

Samples of coated persimmons were loaded on Instron machine in two load values of 150 and 250. To carry out a mechanical pressure test, a multifunction testing machine called Santam-STM5 (Made in IRAN) with 500 N load cell was applied. For the compression test, two circular plates were used, and this test was performed at a rate of 10 mm min^{-1}. To minimize the error, all loadings were performed in one direction for all persimmons. Figure 1 shows the placement of the samples (Vahedi et al., 2020).

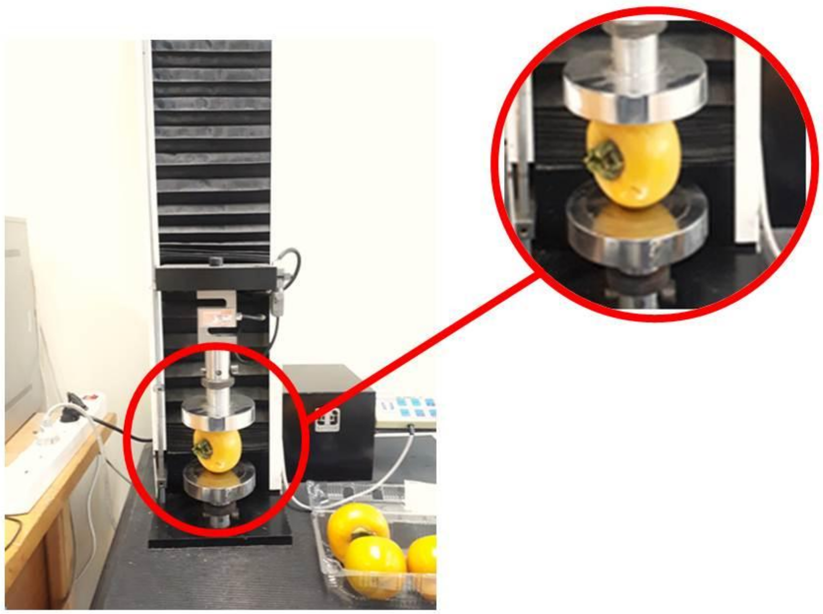


Figure 1 Persimmons loading and the manner of loading

Figure 2 Used packages in this research

A: Foil container packs with polyolefin film; B: Polyethylene terephthalate; C: Ordinary box

2.5 Qualitative measurements

To measure the qualitative properties of persimmon, fruit juice was taken and passed through a paper filter. Then 0.5 g of fruit juice solution was homogenized entirely with 5 mL of 80% methanol (in a ratio of 1 to 10). The samples were then placed in the dark environment and settled on a shaker for 24 hours. Subsequently, the samples were centrifuged at 3000 r/min for 5 minutes, and the upper part of the extract was used to measure the desired properties.

2.6 Percentage of free radical scavenging using DPPH method

In this test, the first 2 mL of DPPH with a concentration of 0.1 mMol L^{-1}, formed by adding 0.4 mg DPPH in 100 mL of methanol, was transferred to the test tube and then 2 mL of methanol extract was prepared and added to it. After that, the test tubes were placed in a dark environment for 15 minutes and immediately read with a 2800UV / VIS spectrophotometer (Camspec M501) at 517 nm wavelength. The control sample contained 2 mL DPPH and 2 mL methanol. The calibration of the spectrophotometer with methanol was taken place, and the obtained numbers were converted to scavenging percentage as represented in the Equation 1 (Azadbakht and Torshizi, 2020):

$$\boldsymbol{DPPH = \frac{A_C - A_S}{A_C} \times 100} \quad (1)$$

Where: Ac is the absorption of control sample, and As is the absorption of samples.

2.7 The amount of total phenol

The measurement of the value of total phenol was fulfilled using Folin Ciocâlteu method. To this end, 2 μL of methanol extract (0.5 g in 5 mL of 80% methanol) was mixed with 100 μL of Folin Ciocâlteu and 1.16 mL of distilled water. After 5 to 8 minutes rest, 300 μL of 1 M sodium carbonate containing 10.6 g in 100 mL of distilled water was added. The above solution was placed in a steam bath (at a temperature of 40 ℃) for 30 min. Finally, the samples were read on a spectrophotometer at 765 nm wavelength. The amount of total phenol content (*x*) in milligrams of gallic acid per gram was obtained by placing the sample adsorption number instead of *y* in the equation of the line (Equation 2) (Toure et al., 2015) :

$$\boldsymbol{y = 0.0034x - 0.0114} \quad (2)$$

2.8 The number of flavonoids

To determine the number of flavonoids(z), methanol extract was mixed with methanol, 10% aluminum chloride (10 g aluminum chloride in 100 mL of distilled water), 1 M potassium acetate (2.41 g in 10 mL of distilled water) and distilled water. Instead of methanol extract, the only pure methanol was used for preparing the control sample. The mixture was put in the dark environment for half an hour and immediately assigned at a wavelength of 415 nm with a spectrophotometer (D), and then the output number of the device was read. The derived numbers specified for flavonoids were realized by referring to the standard curve. The standard curve was resulted by using formula 3. Therefore, different concentrations were made from the quercetin standard, and, after reading the adsorption number, real numbers and total flavonoid concentrations were provided.

$$\boldsymbol{D = 0.0121z + 0.0722} \quad (3)$$

2.9 Vitamin C

The method of Kashyap and Gautam (2012) was applied to measure the vitamin C of the pomegranate fruit. The concentration of vitamin C was determined by oxidation-reduction (redox) titrations, including iodine and iodite solution. At the time of titer of the iodine solution on the compound containing vitamin C, this vitamin was oxidized as dehydroascorbic acid (DHA). In contrast, iodine was reduced in the form of iodide ions. When the entire vitamin C compound was neutralized, the excessive iodine solution reacted with the starch marker. It turned dark blue so that the titer's endpoint was evident when the solution turned blue-black, and no changes happened in color. To titrate the juice samples, 20 mLof the juice sample was poured into a 250 mL Erlenmeyer flask, and 150 mL of distilled water was added. Then 1 mL of 1% starch index solution was removed and added to this solution. The compound was titrated with iodine solution and carried on until observing dark blue and black colors. Vitamin C was considered in each milligram per 100 milliliters of fruit juice. Each milliliter of iodine consumed dye in potassium iodide, which changed the juice color, was estimated to be equal to 0.88 g of ascorbic acid (AOAC, 1990). Vitamin C amounts were derived from Equation 4.

$$\text{Vitamin C= The volume of consumed iodine} \times 0.88 \quad (4)$$

To prepare the iodine solution, 5 g of potassium iodide

(KI) and 0.268 g of potassium iodite (KIO_2) was poured into a 500 mL dish and dissolved in 200 mL of distilled water. Then 30 mL of 3 M sulfuric acid was added to the container, and after that, up to 500 mL of distilled water was added to dilute the solution. For preparation of the 1% starch index, 1 g of starch was first weighed and added to 100 mg of near-boiling water in a 100 mL Erlenmeyer flask and dissolved completely. This solution was required to be cooled before its use.

2.10 pH

Respecting the standard of Iran No. 2685, the pH of all samples were measured at the temperature of 20 ℃ by digital pH meter named pHS-3BW (MICROPROCESSOR) pH/Mv made in Italy

2.11 Acidity

The amount of titratable acidity was determined by titration with sodium hydroxide (0.1 Nl) For this purpose, 2 mL of fruit juice was diluted in 38 mL of distilled water. Then 3 drops of phenolphthalein solution (1% alcohol) were added to it and titrated with 0.1 Nl sodium hydroxide until the appearance of pale pink color and reaching the pitch of the solution to 1/8. The acidity rate was expressed in terms of percentage of citric acid.

2.12 Dissolved solids

The percentage of dissolved solids in fruit juice was measured using a digital refractometer (CETI, ABBE, Belgium) made in Japan. The concentration of the solution was obtained from fruit juice in degree brix (Yousefi and Akhavan, 2011).

2.13 Statistical analysis

The study was performed on the physical properties of persimmons. Independent parameters included loading force at 2 levels of 150 and 250 N, three types of foam container packaging with polyolefine film, polyethylene terephthalate, and ordinary box, four types of polyamine coatings with concentrations of 1 and 2 Millimolar, distilled water and non-coated. The chemical properties of persimmon fruit including the number of antioxidants, total phenol, flavonoids, vitamin C, pH, acidity and dissolved solids were examined as a dependent factor. All experiments were performed in three replications and the results were analyzed using factorial experiments and in a completely randomized design using SAS statistical software.

3 Results and discussion

The results obtained from independent factors of loading force, coating, and packaging on properties including antioxidants, total phenol, flavonoids, vitamin C, pH, acidity, and dissolved solids of persimmon are presented in Table 1.

Table 1 Results of variance analysis of antioxidants, total phenol, flavonoids, vitamin C, pH, acidity and dissolved solids of persimmon

	Antioxidant Content		Phenol Content		Flavonoid Content		Vitamin C Content	
	Mean square	F value	Mean square	F value	Mean square	F value	Mean square	F value
Loading	158.08	5.17*	162.27	1.77	102.36	10.998**	3.54	0.93
Coating	1552.37	43.36**	2248.62	24.48**	37.08	3.94*	31.69	8.29**
packing	646.21	18.05**	451.57	4.92*	16.53	1.76	21.93	5.74**
Loading× Coating	4.74	0.13	5.28	0.06	32.90	3.49*	0.400	0.10
Loading× packing	0.66	0.02	28.30	0.31	50.55	5.37**	0.560	0.15
Coating× packing	10.63	0.30	301.60	3.28*	26.28	2.79*	0.708	0.19
CV	10.65		12.03		5.41		15.15	
	pH		**Acidity**		**Solid soluble content**			
	Mean square	F value	Mean square	F value	Mean square	F value		
Loading	0.059	0.61	0.026	6.4*	21.20	6.56*		
Coating	1.22	12.54**	0.093	22.21**	74.38	23.01**		
packing	0.128	1.32	0.068	16.35**	64.04	19.81		
Loading× Coating	0.528	5.42**	0.00011	0.03	0.22	0.07		
Loading× packing	0.048	0.50	0.0023	0.57	0.32	0.10		
Coating× packing	0.0091	0.09	0.0013	0.33	1.54	0.48		
CV	4.94		12.27		10.09			

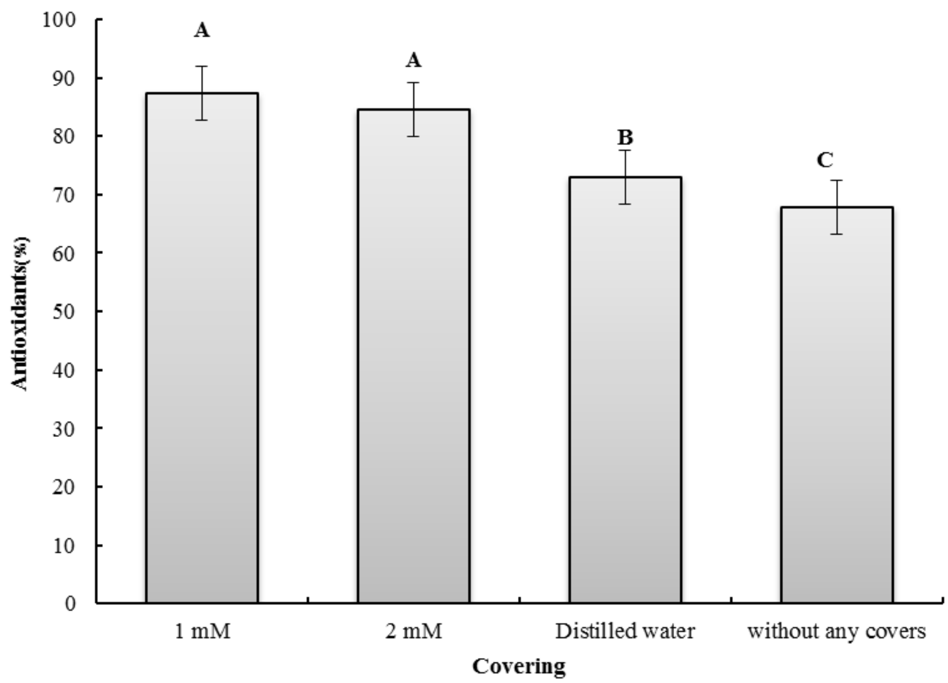
Note: **= Significant at 1% level/ *= Significant at 5% level/ ns= not significant

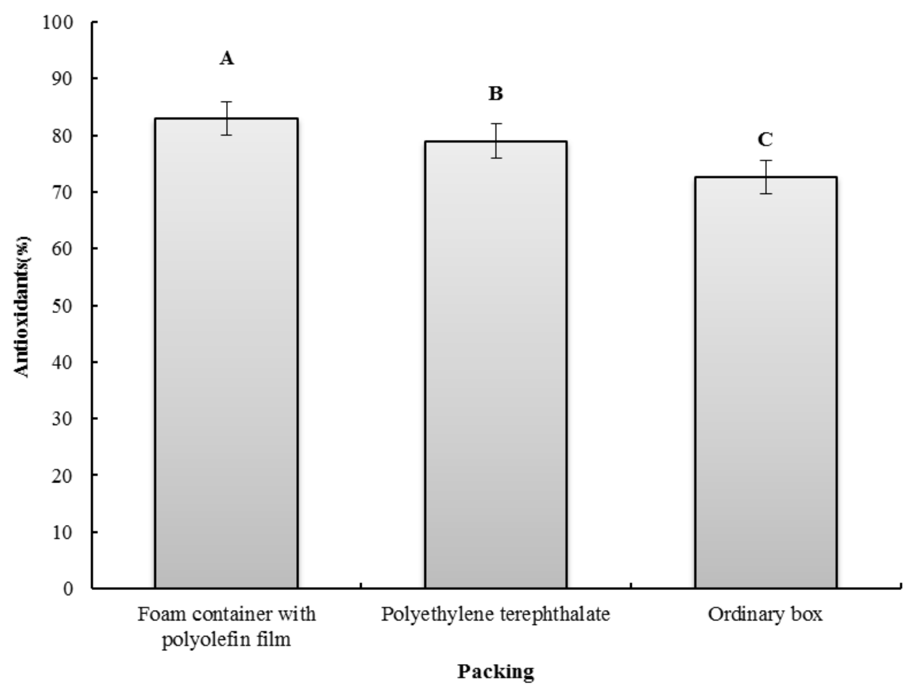
It was found out that for antioxidant properties, the factors of loading, coating, and packaging were significant at the level of 5%, 1%, and 1%, respectively while the interaction effect of these factors was not considered significant on the antioxidant properties. The independent loading factor was not significant for total persimmon phenol, but coating and packaging for total phenol were statistically significant at 1% and 5%, respectively. Also, among the interaction effect of independent factors, the interaction effect of packaging in the coating was statistically significant at 5%. In studying flavonoid for persimmon fruit, it was realized that loading and coating were statistically significant at the level of 1% and 5%, respectively. The packaging factor did not impose a significant effect. Also, the interaction effect of loading on the coating and packaging in the coating was 5% statistically significant for flavonoids, and loading in packaging for this factor was statistically significant at the level of 1%. Vitamin C dependent factor was also examined in this study, and it was recognized that loading and interaction effects for this factor were not significant. The coating and packaging for vitamin C were statistically significant at the level of 1%. In the study of pH for persimmon samples, coating, and the interaction effect of coating on loading were only significant at the statistical level of 1%. Except for these two cases, none of the independent loading and packaging factors and their interactions was found significant. In the case of persimmon acidity, the loading factor was observed significant at the level of 5%, and the coating and packaging at the statistical level was 1%. The interaction effect of these factors was not significant for the acidity of the persimmon. In the dissolved solids' case, the significance of the intended factors was exactly similar to that of the persimmon acidity. Concerning achieved values, the interaction effects of significant factors were analyzed by LSD statistical analysis. The related results were illustrated in the figures in the following parts of this section.

3.1 The number of antioxidants

Following the significance of independent factors of packaging, loading, and coating, a mean comparison was performed, and the results for antioxidants were shown in Figure 3.

Part A of this figure shows that making use of different packaging left a significant effect on the amount of antioxidants in persimmon, so that the highest amount of antioxidants (82.93%) was observed on the foam side with polyolefin film and the lowest amount (72.64%) was obtained in packaging with ordinary boxes as existed in the market. Moreover, the loading was significant for persimmon antioxidants, and there was a significant difference between different loadings, in which the highest value was observed in 150 N loading equal to 79.79%. Based on the coating results, no difference was found between 1 mM and 2 mM putrescine coating. Still, the putrescine coating antioxidant was significantly different from the antioxidant of coating and uncoated distilled water. Additionally, the use of distilled water as a coating exhibited a different amount of antioxidant significance than uncoated fruits. The highest amount (87.37%) was considered in 1 mM putrescine coating, and the lowest amount (67.89%) in uncoated persimmons. Quasi-static compression led to a reduction in the strength of the fruit during storage and increased the percentage of bruising due to pressure on fruit tissues and shear and flexural stresses in that area. Following the increased bruising, the cellular structure of the fruit was destroyed more rapidly. Overlooking the conductive effects of free radicals and protecting cells from oxidative damage caused a reduction in the percentage of fruit antioxidants. Therefore, by increasing the amount of loading force, the antioxidant amount was often reduced, and there existed an inverse relationship between the amount of antioxidant and the loading force (Torres et al., 2010). Also, the diminution of free radical scavenging activity in uncoated samples could be due to decreased phenolic compounds and acid ascorbic during the storage period. Concerning greater protection of phenolic compounds by foam containers with polyolefin and coating with 1 mM concentration, an increase was observed in the free radical scavenging activity. Through creating a modified atmosphere and reducing respiration and transpiration of the fruit, polyolefin coating resulted in maintaining acid ascorbic and increasing the concentration of antioxidant capacity (Ma et al., 2012) . Different researchers realized similar relationships between loading force and coating with the antioxidant amount of different fruits (Azadbakht and Vahedi, 2020, Baratta et al., 1998).





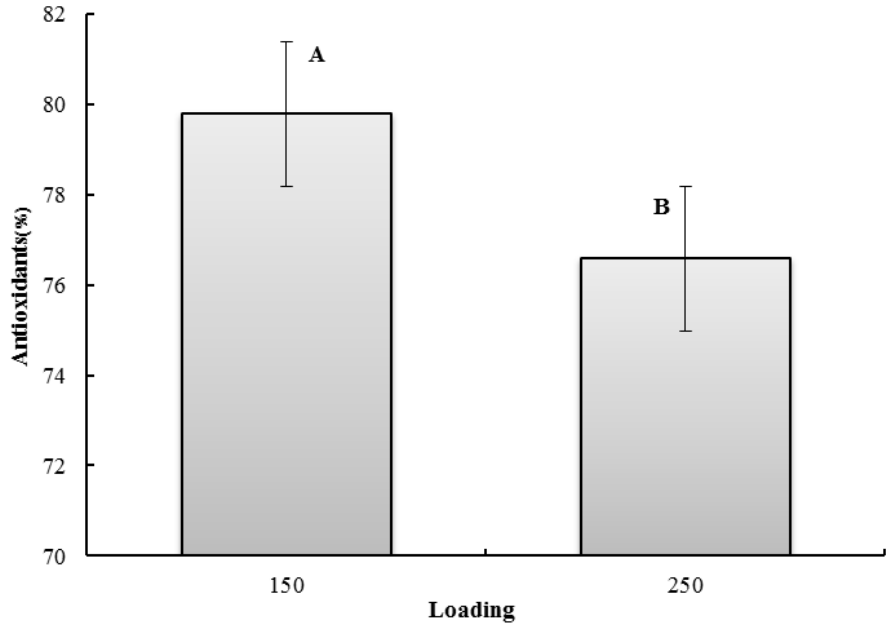


Figure 3 Mean comparison of packaging, loading, and coating for the number of persimmon antioxidants

A. Covering- Antioxidant, B. Packaging-Antioxidant, C. Loading- Antioxidant

Note: A similar capital letter represented no significant differences at different levels

3.2 The amount of total phenol

The interaction effects of packaging and coating were obvious in Figure 4 which shows that using foam containers with polyolefin films could be subject to more phenol in persimmon fruits, and the least amount of phenol also accompanied the using ordinary boxes.

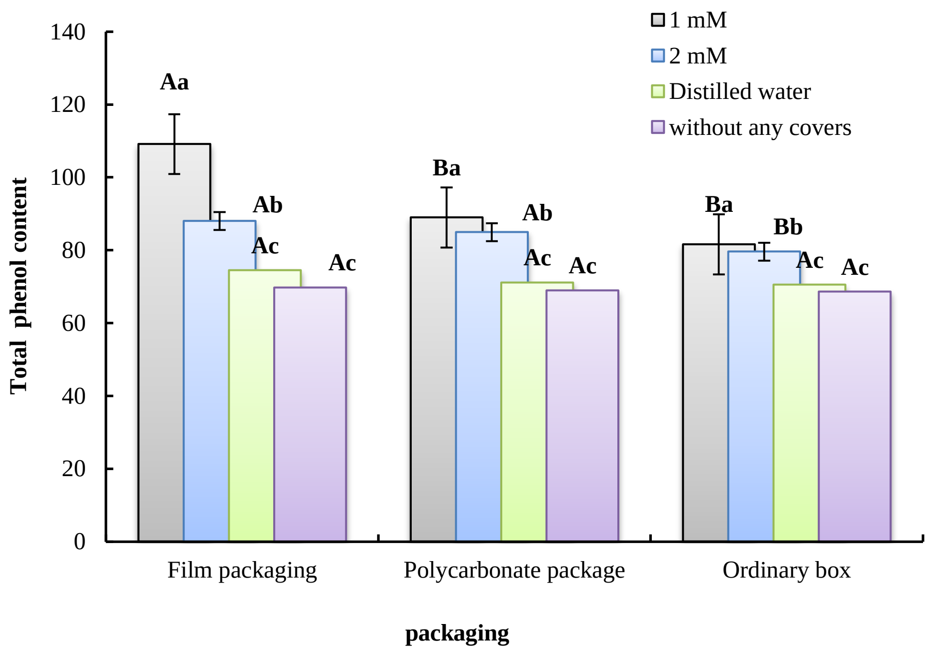


Figure 4 Interaction effects of packaging and coating on the total phenol content of persimmon

Note: Common capital letters represented no significant difference in a fixed coating, and small letters represented no significant difference in a fixed packaging.

The other finding induced by this Figure was that in all three types of packaging, there was a significant difference between 1 mM and 2 mM putrescine coating, distilled water and uncoated distilled water, but distilled water coatings and uncoated distilled water created no significant difference for total phenol content. Moreover, using coated and uncoated distilled water was accompanied by a significant difference in persimmon in different packages, addressing that making use of distilled water did not have a positive effect. The obtained values were not significant in all packaging in these coatings. In case of 1 mM coating, the packaging of the foam container with polyolefin film had a significant difference with the other two packages and the other two packages did not indicate a significant difference in phenol content, meaning that 1 mM putrescine coating could not create a significant effect on the packaging of polyethylene terephthalate container with ordinary boxes. In the 2 mM putrescine coating, there was no significant difference in the foam container packaging with polyolefin film and polyethylene terephthalate. Still, these two packages revealed a significant difference with the phenol content of the ordinary box. Also, making use of coated and uncoated distilled water exhibited no significant difference compared to each other in any of the packages. Given the extracted results, the highest value of total phenol content (109.13) was obtained in 1 mM putrescine coating and foam container packaging with polyolefin film and the lowest amount (68.61) in uncoated persimmons and ordinary box packaging. The reason for these results was that fruit coating reduced the amount of oxygen, delayed physiological processes, restricted the access of polyphenol oxidase and peroxidase enzymes to oxygen, and inhibited the diminution of phenols during storage. Fernandez-Panchon et al. (2008) also achieved similar results in line with this part of the study (Fernandez-Panchon et al., 2008). In similar cases of researches, Hosseini et al. (2018b) studied the effect of post-harvest polyamine application and edible coating on maintaining the quality of mango during shelf life in the cold storage. In this study, using chitosan containing ascorbic acid significantly increased the phenolic content and antioxidant activity compared to control plants (Hosseini et al., 2018b). Furthermore, the previous reports represented that the chitosan coating significantly reduced the respiration rate in peach fruits and prevented the oxidation of the phenols (Li and Yu, 2001).

3.3 The amount of flavonoid

The amount of flavonoid is presented in Figure 5, it was obvious that the increased loading reduced the amount of flavonoid content in persimmon fruit, which was significant in all coatings. Still, no significant difference was cleared for uncoated persimmons. Also, given the obtained results, it was declared that in 150 N load, no significant difference was evident between the three coatings of 1 mM and 2 mM Putresin and distilled water. Still, uncoated persimmon was significantly different from these values. In 1 mM putrescine coating could lead to a significant difference, and no significant difference was considered for 2 mM putrescine coating and distilled water. Still, the flavonoid content of uncoated persimmons was also significantly different from other coatings. The highest flavonoid content of 6.97 MQ / 100Gfw was found in 1 mM putrescine coating and 150 N loading force, and the lowest flavonoid content was also obtained in 250 N loading force and uncoated state with 4.27 QMQ / 100Gfw state. To elucidate the reason for these results, it was stated that the living cell of the fruit needed respiration to survive. During fruit storage, respiration usually continued more intensely, and this change could be a result of intracellular activity and energy supply to them. In coated fruits, increasing cell respiration was slower, which was finally due to the reduction of cell pore diameter from the fruit coating. Subsequently, due to the decrease in the fruit respiration process, the flavonoids were prevented from spoilage, and their value was higher in coated fruits. In similar conducted works, treated fruits with calcium chloride had higher values of total phenol and flavonoids than fruits in the control group. This was in line with reported results in blueberries (Aghdam et al., 2013) and pears (Kou et al., 2014).

The results achieved from the interaction effect of packaging and coating on flavonoid content were illustrated in Figure 6.

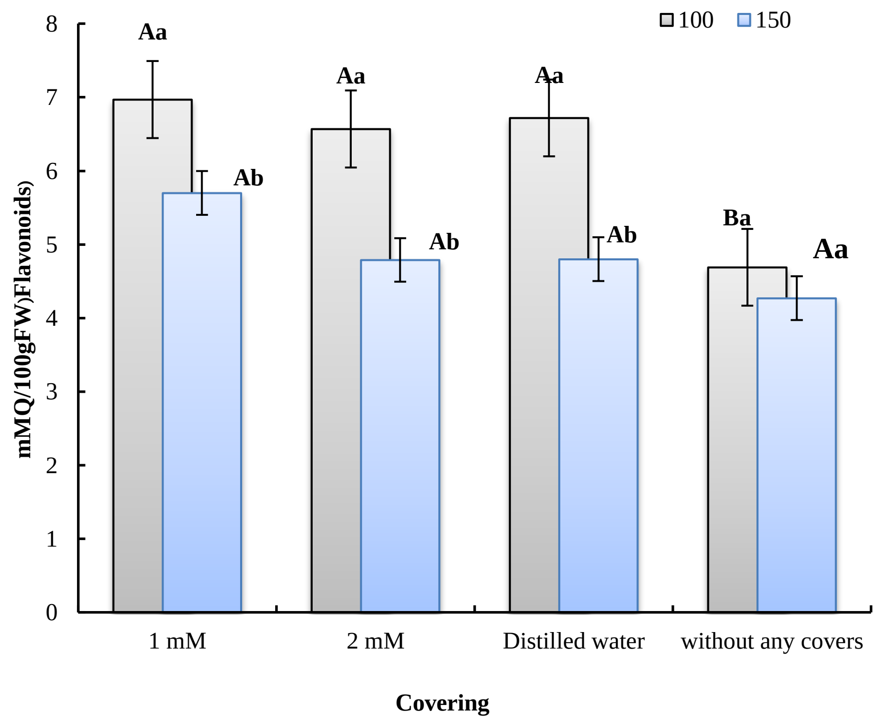


Figure 5 Interaction effect of loading and coating on the flavonoid content of persimmon

Note: Common capital letters represented no significant difference in a fixed coating, and small letters represented no significant difference in a fixed packaging.

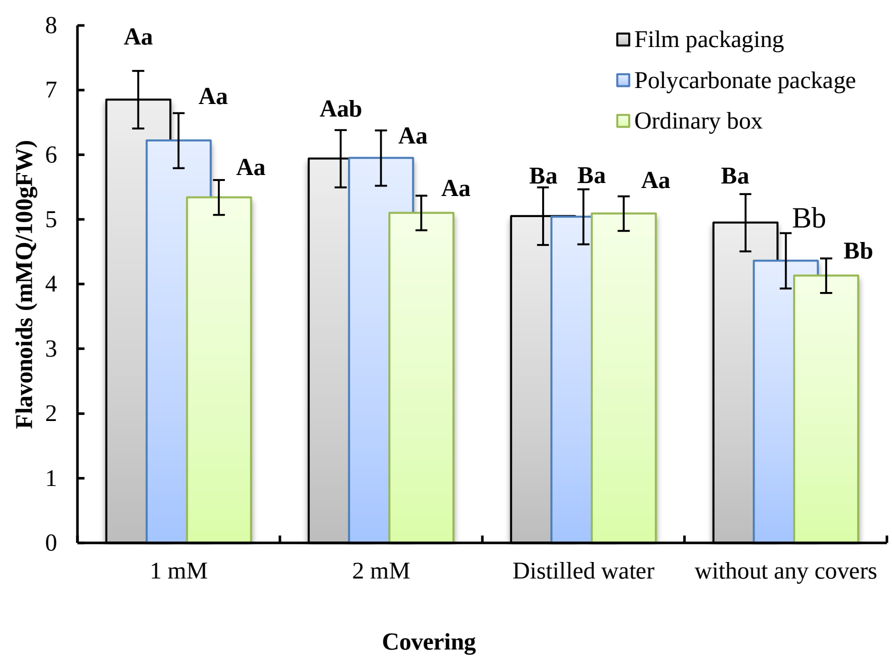


Figure 6 Interaction effect of packaging and coating on the flavonoid content of persimmon

Note: Common capital letters represented no significant difference in a fixed coating, and small letters represented no significant difference in a fixed packaging.

It was observed that in the case of packaging in a foam container with polyolefin film, there was no clear significant difference between putrescines 1 and 2 mM and also the distilled water coating and uncoated distilled was not significantly different in the amount of flavonoid. Regarding the packaging with polyethylene terephthalate containers, consistent results were extracted with packaging with foam containers with polyolefin film. Still, the amount of flavonoid content in all coatings in this packaging was observed less than the same coatings in packaging with foam containers with the help of polyolefin film. In the case of packaging with an ordinary box, there existed no significant difference between 1 and 2 mM putrescine coatings and distilled water. Still, these coatings revealed a significant difference with the uncoated state of persimmons in ordinary box packaging. Also, in coating with putrescine in 1 mM and 2 mM states, no significant difference existed between packaging and foam containers with polyolefin film and polyethylene terephthalate in flavonoid content. Still, these two packages were significantly different from ordinary box packaging. Besides, for coating with distilled water, no significant difference was evident between all three boxes. Still, in the uncoated state, there was a significant difference between packaging with a foam container with polyolefin film and the other two packages. It was found out that the highest amount of flavonoid content (6.851 µMQ / 100Gfw) was observed in packaging with foam containers with polyolefin film and 1 mM putrescine coating, and the lowest amount (4.13 µMQ / 100Gfw) was obtained in the packaging of ordinary box and uncoated state. The presented findings from the obtained values in this Figure were due to the presence of edible coatings. Edible coatings originated the biotic stress on the product, changed its metabolism, and influenced the production of secondary metabolites such as phenolic compounds and flavonoids. The study in line with the present study, conducted by Karuku et al. (2014), investigated the effect of edible coatings on bioactive compounds and antioxidant capacity of tomato at different maturation stages. The results illuminated that the total phenolic and flavonoid content for the coated fruits was significantly less than the control fruits. The achieved data in this study was led from making use of edible coatings, as a safe and suitable substitute, to maintain the quality of tomato (Karuku et al., 2014).

Figure 7 indicated the effects of the interaction effect of loading and packaging on the flavonoid content of persimmon fruit. It was referred that the increased loading force led to a significant decrease in the flavonoid content in different packaging containers. Also, in a fixed loading force of 150 N, there was no significant difference between polyethylene terephthalate packaging containers and ordinary boxes. Still, these two boxes showed a significant difference with foam packaging containers with polyolefin films. On the other hand, at the loading force of 250 N, no significant difference was cleared between any packaging containers. The highest value of flavonoid content in the interaction effect of loading and packaging in 150 N load and packaging with foam packaging containers with polyolefin film was considered to be 6.83 QMQ / 100Gfw. The lowest value (4.183 QMQ / 100Gfw) was observed in ordinary box containers and loading force of 250 N. While increasing the loading force by the continuation of cellular respiration and enzymatic activity, the fruit was firstly softened and became squashed. Following this process, moldiness happened as a result of the dissolution of pectin in the intracellular fluid. Therefore, the above results could be justified by an increase in the intercellular moldiness. These results were in line with the researches by Hernández-Muñoz et al. (2006) and Vargas et al. (2006). The results of this study were similar to the results of research conducted on strawberries (Vu et al., 2011).

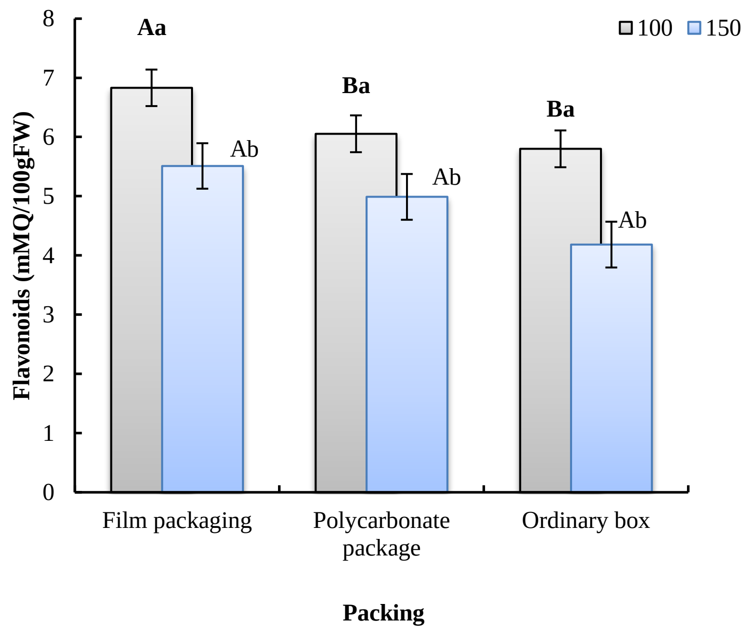


Figure 7 Interaction effect of packaging and loading on the flavonoid content of persimmon

Note: Common capital letters represented no significance in a fixed loading, and small letters represented no significant difference in a fixed packaging.

3.4 Vitamin C

Part A of Figure 8 which illustrated the effect of coating on the value of vitamin C, indicated that there existed no significant difference between the two concentrations of putrescine 1 mM and 2 mM, but making use of putrescine treatment could create a significant effect compared to distilled water and uncoated state for vitamin C of persimmon fruit, subsequently making use of distilled water could not have a significant difference relative to uncoated state and both coatings were assigned in the same statistical group. Also, in the mean comparison of vitamin C in different packages, as evident in Figure 8.B, there was no significant difference between the foam container and the polyolefin film compared to the polyethylene terephthalate packaging containers. Still, these two packages showed a significant difference compared to the stored persimmons in an ordinary box. The positive effect of using these two packages was regarded in keeping the amount of vitamin C high. The highest amounts were considered in the coating for 1 mM putrescine coating with the amount of 14.36 mg 100 g^{-1} FW and in the packaging with foam containers with polyolefin film 13.7 mg 100 g^{-1} FW.

Moreover, the lowest values in the uncoated state and the ordinary box were equal to 11.48 and 11.84 mg 100 g^{-1} FW, respectively. The reason was that surface coating, due to decreased sensitivity of fruits from colding and prevented water loss, inhibited a severe decrease in vitamin C during storage and was conducive to its preservation and maintenance. It was also found out that vitamin C was considerably high in ethylene-free environments. The presented reasons for the achieved results in the current study were in line with the results of the study by Vargas et al. (2006). Similar studies on strawberries reported decreased organic acids during storage in cold storage (Xi et al., 2017). Following, Mirdehghan et al. (2015) researched the application of polyamine coatings on qualitative properties. Their results illuminated that variations in different color indices, vitamin C, total dissolved solids, total acid, and pH in treated fruits were delayed compared to the control group.

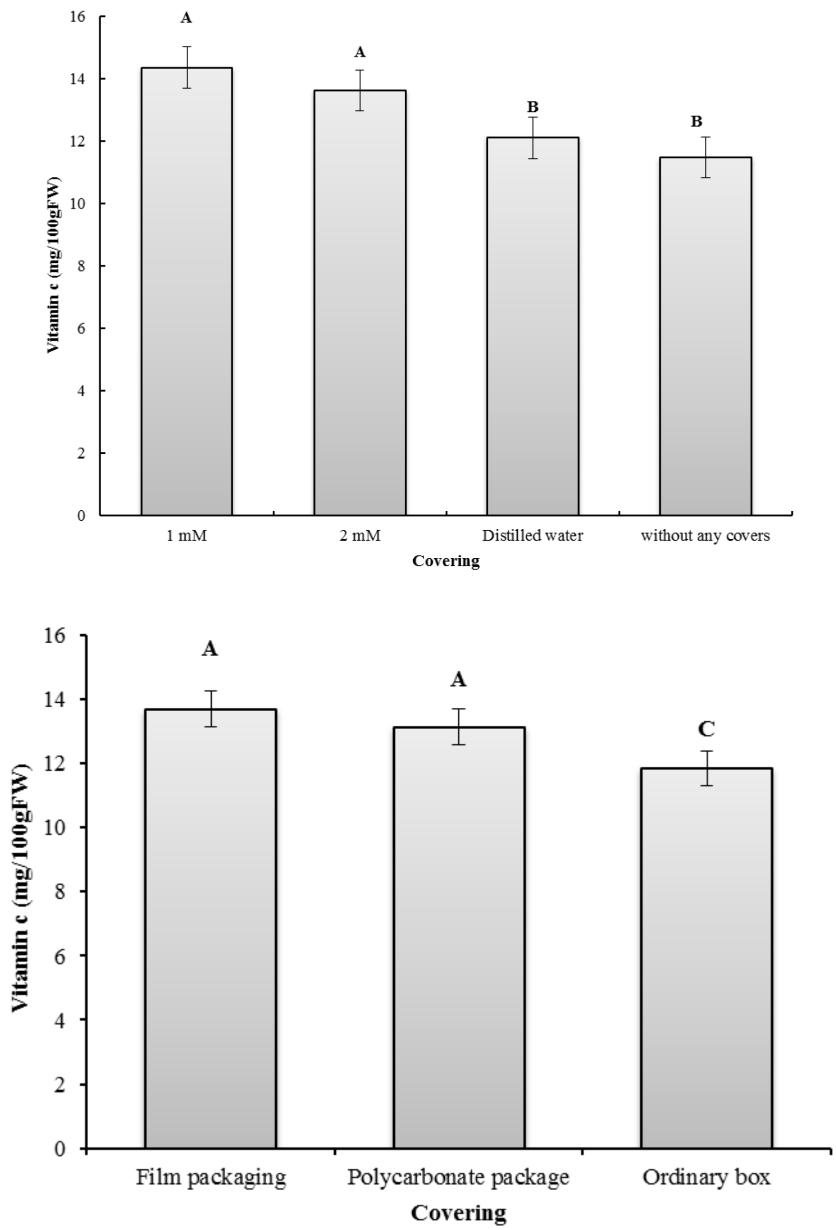


Figure 8 Mean comparison of coating and packaging on the vitamin C content of persimmon

A: The effect of coating on the value of vitamin C, B: The effect of package on the value of vitamin C

Note: A similar capital letter represented no significant differences at different levels

3.5 The amount of pH

As it was obvious from Figure 9, an increase in the loading force led to an increased value of pH for persimmon, and also, the application of pretreatment was helpful in reducing the pH.

Based on this Figure in the 150 N load, there was no significant difference between the used coatings, but increasing the load from 150 to 250 N caused a significant difference in the use of the coating, and this significant difference compared to the uncoated state and distilled water for the pH value of persimmon was manifested by using 1 mM and 2mM putrescine. Also, the application of 1 mM putrescine for coating expressed a significant difference in the value of pH for loadings, and this was also exhibited in the coating with distilled water. Still, no significant difference happened in uncoated distilled water and 2 mM coating treatment. The highest value (6.83) was obtained in the coating treatment with distilled water and 250 loading force. The lowest value (5.73) in the coating with 1 mM putrescine and loading force of 150 N. Increased value of pH along with an increase in the amount of loading force was as a result of the decline process of increased fruit strength(Cong et al., 2007). Coatings slowed down pH changes and effectively delayed their occurrence and decline process. It was inferred that coatings changed the internal atmosphere and the amount of CO_2 and O_2 around the fruit, thus slowing down the ripening of the fruit (Jiang et al., 2012; Janick, 2003). Researchers in their studies expressed that pH usually increased during shelf life, but the application of coatings decreased pH growth rate (Ghasemnezhad and Shiri, 2010). Hosseini et al. (2018b) investigated the effect of the application of post-harvest polyamine and edible coating on maintaining the quality of mango during shelf life in the cold storage. In this survey, using chitosan containing ascorbic acid significantly increased phenolic content and antioxidant activity relative to control plants. It also altered the dissolved solids content, titratable acidity, dough pH, sugar, and reduced ethylene production (Hosseini et al., 2018b).

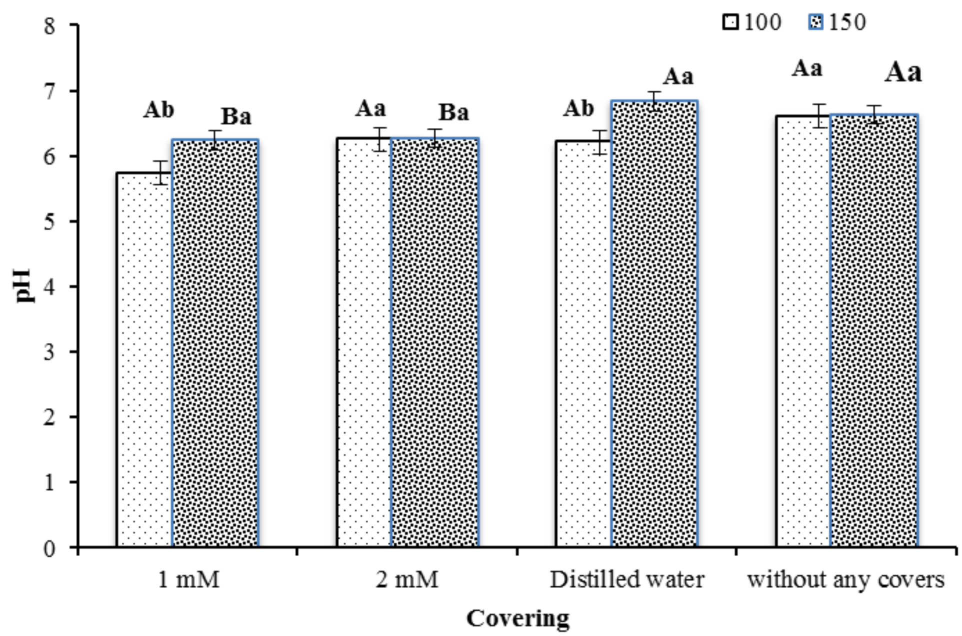


Figure 9 Interaction effect of covering, loading and packaging on the pH content of persimmon

A: Effect of covering on the pH content, B: Effect of loading on the pH content, C: Effect of packaging on the pH content

Note: A similar capital letter represented no significant differences at different levels

3.6 The amount of acidity

The mean average of the acid content of persimmon is provided in Figure 10. It was observed in part A that there was a significant difference between all four coatings. The 1 mM coating was succeeded in obtaining the highest value for acidity, which was equal to 0.608%. For packaging, a significant difference was observed between all three packaging containers, and packaging with foam containers with polyolefin film could get the highest acidity for persimmons, equal to 0.57%. Also, increasing the loading force reduced the persimmon acidity and a significant difference was observed between the two forces used, in which the highest value was obtained in the loading force of 150 N with a value of 0.546% and the lowest values were existed in the uncoated treatment, ordinary box and 250 N loading force with the values equal to 0.44, 0.471 and 0.507, respectively. Extending the time of shelf life led to an increase in the samples' pH and thus a decrease in the amount of acidity. While using the surface coating on the samples, a decline appeared in the pH value and finally, an enhancement in the value of fruit acidity. Increasing the concentration of the coating also inhibited the respiration and decreased acidity(Jiang and Li, 2001). Furthermore, the application of foam containers with polyolefin coating minimized the aging period, and hence making use of this coating enhanced the value of acidity. Slowing down the aging process also was led as a result of reduced ethylene production.

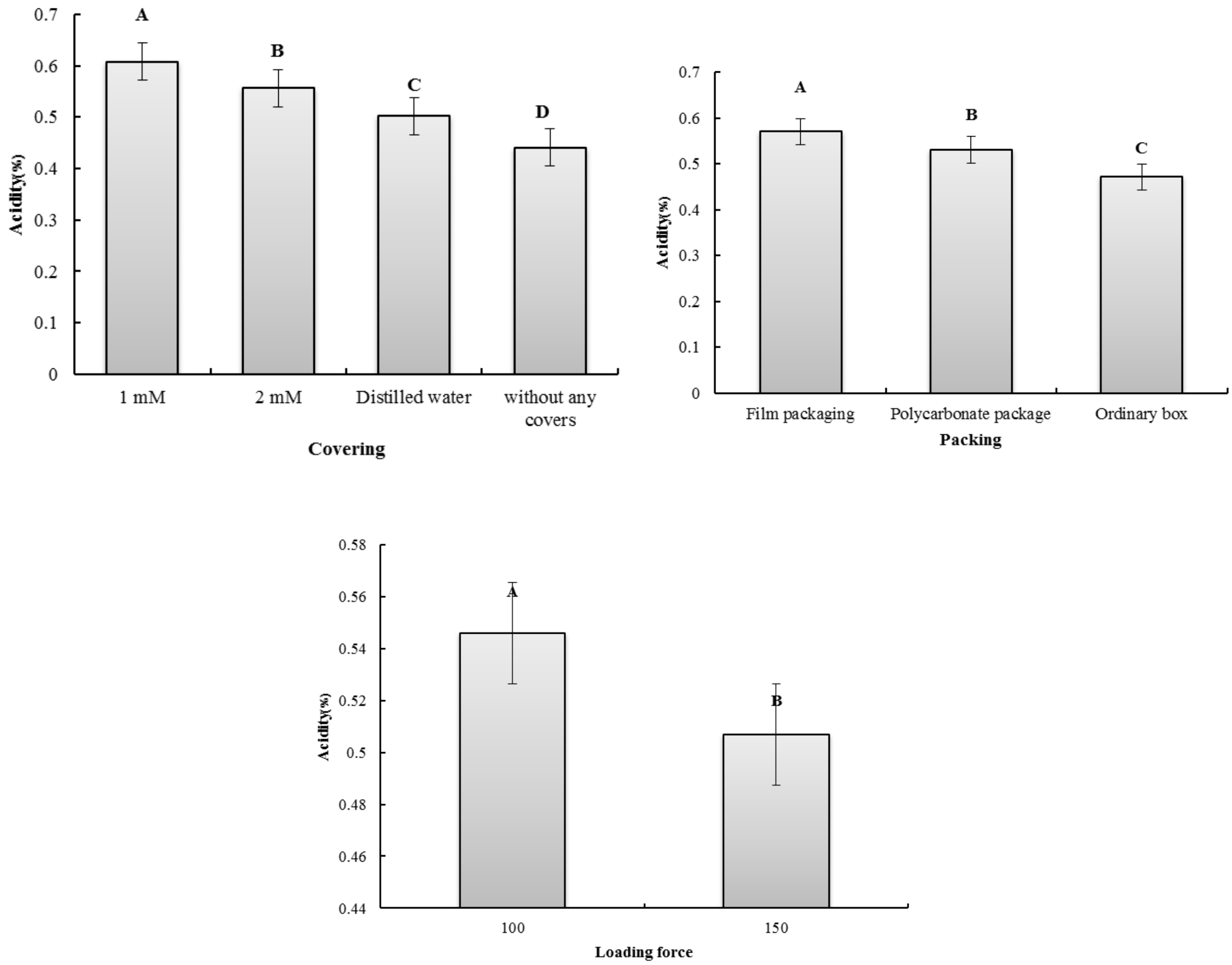


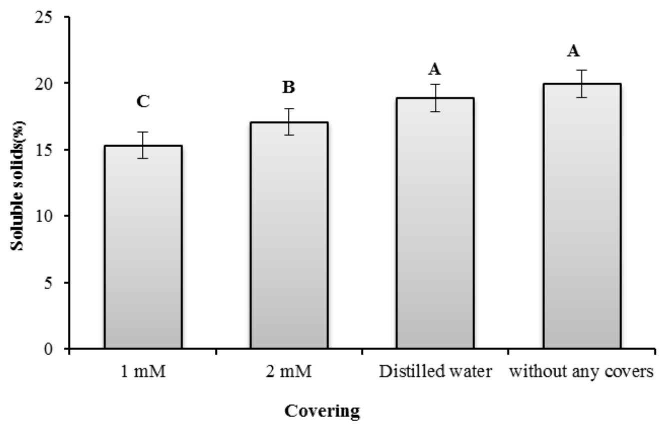
Figure 10 Mean comparison of coating, packaging and loading force on the acid content of persimmon

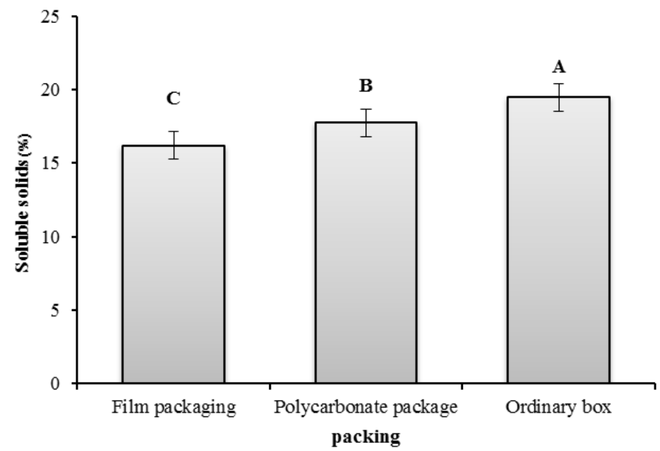
A: Covering - acid content, B: Packaging - acid content, C: Loading - acid content

Note: A similar capital letter represented no significant differences at different levels

3.7 The number of dissolved solids

Figure 11 presented the results of the mean comparison of the coating effect, packaging, and loading force. Respecting to part A of this figure, it was found out that the application of putrescine coating treatment could significantly affect the dissolved solids of persimmon and even create significant differences between 1 mM and 2 mM putrescine; but there was no significant difference in case of uncovered and distilled water. For packing, there was a significant difference between all three types of packaging, which was obvious in part B of the figure, and part C of the Figure revealed a significant difference between loading forces of 150 N and 250 N. Given the obtained results, the highest amount of dissolved solids for persimmon in the uncoated state, ordinary box and loading force of 250 N was equal to 19.94, 19.47 and 18.35, respectively, and the lowest amount of dissolved solids for persimmon was also 15.33, 16.21 and 17.27, respectively, which a foam container with polyolefin film as well as a loading force of 150 N was achieved in the state of 1 mM coating. The reason existed for the leaded result was explicated in the following. The release of steam between the internal and external phases was the first mechanism of weight loss in freshly harvested fruit, ultimately causing an increase in the transpiration and weight loss of the fruit. Also, placing the fruit's coatings on the outer surface of the fruit changed the fruit's inner atmosphere and changed the value of CO_2 and O_2 around the fruit and finally delayed the ripening of the fruit. Delay in fruit ripening could be interpreted as a sign of slowing down the rate loss of moisture content and consequently reducing the weight of the samples. This finding was justified following the reduced rate of loss of moisture content and a direct relationship between the reduction rate and dissolved solids' value. The provided reasons for the results of this part were found consistent with the results of the works by Suseno et al. (2014), Jiang et al. (2012) and Janick (2003). Also, in similar tests, the positive effect of chitosan coating on preventing the weight loss was reported in strawberry fruit Hernández-Muñozet al., (2006), guava (Hong et al., 2012)and fungi (Jiang et al., 2012).





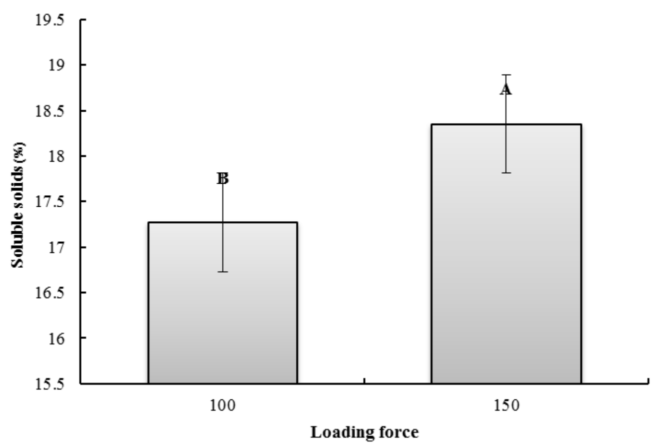


Figure 11 Mean comparison of coating, packaging and loading force on the dissolved solids content of persimmon

A: Covering - dissolved solids content, B: Packaging - dissolved solids content, C: Loading - dissolved solids content

Note: A similar capital letter represented no significant differences at different levels

4 Conclusion

The antioxidant properties of compressed Persimmon fruit using Putrescine Coatings and Polyamine Films was investigated. Antioxidant content showed a significant effect on packing and loading in all factors and Putrescine covering was a significant effect between all covering factors. Also in the phenol content and solid soluble content have observed a reducing rate in packing and in the packing by foam container packages with polyolefin film and poly amine covering were higher amount and lower changing. For Flavonoid content the best and highest amount were at poly amine covering and weren't different significant between both of poly amine amount and foam container packages with polyolefin film packing had the lowest changing than other packs and is observed a similar result by this factor for acidity content. Just ordinary box for vitamin-C had a significant effect between all packs and wasn't a different significant effect between two other packs. The best amount for pH content which is lower than distilled water and Non-covering was obtained at poly amine covering. Loading factor had a negative effect on component persimmon and putrescine treatment in foam container packages with polyolefin film had the best component persimmon amount.

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