Improving Postharvest Quality of Sweet Cherry Fruit by Using Tragacanth and *Eremurus*

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**ABSTRACT**
Reducing post-harvest losses and increasing the shelf life of agricultural products leads to reduced production costs. Edible coatings are used to improve fruit quality and increase the shelf-life of horticultural commodities. Therefore, this study aims to investigate the possible effect of edible coatings, including tragacanth gum (TG), *Eremurus* extract (EE) and tragacanth + *Eremurus* at 0, 7.5, 10, and 12.5 g L⁻¹, on the fruit quality of ‘Takdaneh Mashhad’ sweet cherry cultivar. Fruits were immersed in the treatment solutions for 3 min and air dried. Then after weighing and labeling, they were collected in fruit baskets and transferred to a cold storage at 0 ± 1°C and 85 to 90% relative humidity. These fruits were taken out of the cold storage at the beginning of the experiment and after 15, 30, and 45 days for measuring fruit weight loss, fruit firmness, soluble solids content (SSC), pH, titratable acidity, total phenolic content, polyphenol oxidase enzyme activity, vitamin C, fruit-edible quality, fruit color, and decay index. According to the results, fruits coated with 12.5 g L⁻¹ TG and also 12.5 g L⁻¹ EE coatings individually showed reduction in weight loss compared to the control treatment. These two treatments increased the qualitative appearance of the fruit such as fruit firmness, color and vitamin C compared to the control fruits. All coating treatments reduced decay index. The present study was the first study to investigate the effect of *Eremurus* alone or in combination with tragacanth gum on the physicochemical properties of sweet cherry fruit.

**KEYWORDS**
* Astragalus sp; edible coating; *Prunus avium*; ‘Takdaneh Mashhad’; weight loss

**Introduction**
The sweet cherry (*Prunus avium* L.) belongs to the family Rosaceae, and is highly perishable. It is susceptible to physiological disorders such as pitting, fungal rots that limit shelf life of fruits (Alique et al., 2005). The annual world production of sweet cherry was around 2.4 tons and the main producers in the world were Turkey, United States of America, Uzbekistan, Chile, and Iran (FAOSTAT, 2020). Due to high consumer demands in the world and its cultivation in more than 40 countries, its production has increased rapidly. Sweet cherry fruits have significant levels of important nutrients and bioactive components, such as anthocyanins, vitamin C, fructose, glucose, quercetin, and flavanols and the cherry nutrients is highly dependent on pre- and postharvest factors (Cao et al., 2015; Esti et al., 2002; Gao and Mazza, 1995; Martínez-Romero et al., 2006). The most important physical parameters of the fresh cherry consumption market are skin color, firmness, and size of the fruit, and its shine plays a significant role in customer attraction (Esti et al., 2002). Between 5 and 25% of agronomic crops and 10 to 35% of horticultural products
(vegetable and fruit) are decayed as wastes each year. Due to the high level of agricultural waste, and water used in waste generation, reduction of it by improving postharvest life is very important (FAOSTAT, 2012).

Although there are major advances in pre- and postharvest treatments for improving fruit quality and market access, further research is needed to achieve high-quality fruits that meet consumer expectations, such as improved investment returns (Chockchaisawasdee et al., 2016). Edible coatings are thin layers of packaging materials and made from edible products (Hassan et al., 2018). These coatings increase the shelf life, quality, health, and stability of the physical properties of products by creating a semi-permeable barrier to water, oxygen, and carbon dioxide between the products and the surrounding atmosphere. Appropriate coating should pass a certain amount of gases to prevent anaerobic respiration of the product (Lin and Zhao, 2007). Various types of coating materials such as alginate, chitosan, almond gum, gum arabic, whey protein isolate and Aloe vera gel have been used for sweet cherry postharvest (Aday and Caner, 2010; Dang et al., 2010; Mahfoudhi and Hamdi, 2015; Pasquariello et al., 2015; Petriccione et al., 2015). In one study, Aloe vera gel was used to enhance the quality and shelf life of cherry fruit and significantly reduced respiration rate and weight loss percentage of coated fruits compared to uncoated fruits (Martinez-Romero et al., 2006; Ozturk, 2020; Ozturk and Aglar, 2019; Ozturk et al., 2019a). The effect of postharvest application of biofilm (ParkaTM) (Karakaya, 2020), methyl jasmonate (Kucuker and Ozturk, 2014), gibberellic acid (Ozturk et al., 2019b), aminoethoxyvinylglycine (2018), salicylic acid (SA), acetylsalicylic acid (ASA) or oxalic acid (OA) on cherry fruits was evaluated and found that these coatings reduced color discoloration and loss of fruit firmness and retained qualitative characteristics, also total phenolics in all treated fruits increased compared to control (Valero et al., 2011). In one research, the effect of essential oil of Thymus vulgaris and Satureja montana on quality parameters of sweet cherry was investigated. According to the results, the use of essential oils as a vapor decreased weight loss and reduction of vitamin C. Therefore the vapor phase of the essential oils showed the ability to control the postharvest pathogens in the cherries even without direct contact (Maghenzani et al., 2018). An experiment was designed to study the effect of guar gum (GG) and ginseng extract (GSE) on fruit characterstics of sweet cherry and the best result was obtained in combination of GG and GSE (Dong and Wang, 2018). However, Tragacanth gum and Eremurus can be used as edible coatings. Tragacanth gum, also known as katira, is obtained from small, thorny shrubs of the commercial Astragalus species grown in Iran, Syria, and Turkey. TG chemically is a highly branched complex, and anionic polysaccharide comprising small proportions of protein. It consists of two main fractions termed as tragacanthin, which is soluble in water and bassorin, which represents 60–70% of the total gum and has the capacity to swell and form a gel (Balagh et al., 2011; Mayes, 2010; Wang, 2000).

The genus Eremurus (Liliaceae) including nearly 50 species, is native to Eastern Europe and temperate Asia. In particular, Eremurus persicus is particularly valuable in traditional foods and medicines because of its high bioactive compounds. All parts of this plant such as leaves, roots and seeds were used in folk medicine. This plant has antibacterial and cytotoxic activity (Li et al., 2000; Salehi et al., 2017; Vala et al., 2011). There are six species of Eremurus in Iran. Eremurus persicus locally called “Serish” is widely distributed in east, west, and south of Iran and root of this plant is used as natural glue. Leaves have been traditionally used to relieve constipation and treatment of liver, diabetes, and stomach disorders. The chemical constituents of this genus are polysaccharides (Li et al., 2000).

Although there have been no studies on the use of Eremurus as edible coating in postharvest, this research for the first time investigated the effect of this material alone or in combination with TG on the physicochemical properties of sweet cherry fruits and a novel way is provided to improve the fruit quality.

**Materials and Methods**

Sweet cherry fruits (Prunus avium L., cv. ‘Takdaneh Mashhad’) were harvested from commercial orchard located in Eshkevar rural district (90.36° N and 27.50° S), in the Isfahan province, Iran in July 2017. The healthy, uniform, and fully matured fruits were hand-harvested from trees and for further analysis, immediately transported to the laboratory on the same day. This study was conducted
as split plot experiment with a completely randomized design and three replications. In the current research, the effect of four different concentrations (0, 7.5, 10 and 12.5 g L\(^{-1}\)) of tragacanth, *Eremurus* and tragacanth+*Eremurus* on the storage life and edible quality of sweet cherry fruits was investigated at 0, 15, 30, and 45 days of cold storage.

For preparation of the treatments, tragacanth gum was ground, and sieved to produce fine powder. The powdered tragacanth gum at different concentrations (0, 7.5, 10, and 12.5 g L\(^{-1}\)) was added gently to the boiling distilled water and then stirring the solution was done to obtain uniform treatment solutions. After cooling, it was stored in containers with lids. Equation (1) was used to prepare the required concentrations.

\[
x = \frac{a \times b}{c}
\]

(1)  

x: Required volume of base solution (L)  
a: Required solution concentration (g L\(^{-1}\))  
b: required solution volume (L)  
c: Concentration of base solution (g L\(^{-1}\))

To prepare *Eremurus* treatments from each concentrations, the *Eremurus* powder was mixed with distilled water in the desired volume and then stirred well with an Moulinex electric stirrer for 15 min at 25 °C to give a uniform solution treatment. Equation (1) was used to prepare the required concentrations of *Eremurus* like Tragacanth.

After preparation of treatment solutions, for each replications of edible coating treatmets, 60 sweet cherries (each treatment, 180 fruits) were dipped in the treatment solutions for 3 min so that all parts of the fruit were immersed and covered. The selected fruits were healthy and free of any contamination or surface damage. All fruits were air-dried at room temperature for 30 min. Treated fruits, after weighing and labeling, placed in plastic baskets and transferred to the cold storage at 0 ± 1°C and 85–90% relative humidity.

All analyses were conducted at harvest (day 0), and at each period of cold storage, after keeping fruits for 1 day at 25 °C. The traits such as fruit weight loss, Fruit firmness, soluble solids content (SSC), pH, titratable acidity (TA), total phenolics content, polyphenol oxidase enzyme activity, vitamin C, fruit color change, fruit decay, and fruit-edible quality were analyzed and compared with untreated (control) samples.

The weight loss was expressed as the percentage loss compared with the initial weight. To measure the percentage of weight loss, 10 sweet cherry fruits from each treatment were weighed, recorded, and labeled. These measurements were then repeated every 15 days until the 45\(^{th}\) day (Petriccione et al., 2015). The firmness of fruit tissue was evaluated by digital penetrometer and expressed in N (Newton) (Mitcham et al., 1998). The pH of the fruit juices was measured by the pH meter (Metrohm model 827, Switzerland). The total soluble solids content (SSC, °Brix) was determined in the flesh juice using a manual refractometer (N1, Atago). The amount of titratable acid (TA) was determined by titration of fruit juice using 0.1 N NaOH (Guerra et al., 2015). The results are expressed as gram of malic acid per liter of juice.

Polyphenoloxidase enzyme was measured based on cation oxidation (Pizzocaro et al., 1993). The total phenolics content was determined by the Folin Ciocalteu method and expressed as milligrams of gallic acid equivalents (GAE) per 100 g of fruit fresh weight (FW) (Singleton and Rossi, 1965). Vitamin C was analyzed by using 2,6-dichlorophenol indophenol method (Ting and Rouseff, 1986).

In this study, computer image processing method was used to study the color changes of fruit during storage period. The sample color was measured using the CIE L * a * b * model (CIE LAB). This model is the most complete color model officially used to describe all colors visible to the human eye, that three factors L * (red), a * (blue) and b * (green) is measured with this model. To measure the color of the samples, they must first be photographed under the appropriate light. In this study, a Nikon 5300 camera was used in the darkroom. The walls of this room are completely dark and prevent light from being reflected. Fluorescent lamps were used to provide the appropriate light and samples were taken at a distance of 25 cm. The photos taken after transferring to the computer were analyzed by Photoshop CS6 software and the data were recorded. We then use the following equation to obtain overall changes in fruit color:
\[ \Delta E = \left[ (\Delta a^*)^2 + (\Delta L^*)^2 + (\Delta b^*)^2 \right]^{1/2} \]  

(Hashimoto et al., 2006).

The fruits were classified into five groups based on the decays area on each fruit and graded into 0, fruits without surface decay, 1: less than one-fourth of the fruit's surface decaying, 2: between one-fourth to 1 sec of the total fruit surface's decaying, 3: between 1 sec to three-fourths of the total fruit surface's decaying, and 4: fruits with more than three-fourths of the total fruit surface's decaying. The decay index was expressed using the following formula: \[ [(1N1 + 2N2 + 3N3 + 4N4)100/(4 N)], \] where N = total number of fruits measured and N1, N2, N3, and N4 were the number of fruits showing the different degrees of browning. The degree of surface decay was measured through the same scale of browning judgment. For this purpose, each time the samples were taken out of the cold storage, the fruits were carefully evaluated and graded for fungal contamination (Wang et al., 2005).

The edible quality (fruit smell and taste) of the fruits was evaluated by nine test panelists based on 5 points, 5: excellent, 4: good, 3: accep Table 1 and 2: poor and 1: unacceptable (Ayala-Zavala et al., 2004).

**Statistical Analysis**

The data obtained from this study were analyzed based on completely randomized design in split plot using SAS version 9/1. LSD test was used to compare mean data.

**Results**

**Weight Loss**

According to Table 1 and Figure 1, tragacanth and *Eremurus* treatments separately showed better results than combined tragacanth and *Eremurus* treatments. The weight loss increased during storage time. The highest fruit weight loss was observed in the control treatment and all the concentrations of tragacanth and *Eremurus* reduced the percentage of fruit weight loss compared to control. The combination treatments of tragacanth and *Eremurus* at 7.5 g L\(^{-1}\) showed similar results. After 45 days of storage, the lowest fruit weight loss was observed in fruits coated with 10 and 12.5 g L\(^{-1}\) tragacanth and 12.5 g L\(^{-1}\) *Eremurus* coating, respectively.

| Treatment          | Concentration (g L\(^{-1}\)) | Storage time (day) |
|--------------------|-------------------------------|--------------------|
|                    | 0                             | 15                 | 30                 | 45                 |
| Control            | 0                             | 4.4i-k             | 8.15a-d            | 9.4a-b             |
|                    | 7.5                           | 3.17k-m            | 6.53e-h            | 6.69d-h            |
| Tragacanth         | 10                            | 2.25 m-n           | 5.28 h-j           | 7.13d-g            |
|                    | 12.5                          | 1.46 n-o           | 5.32 h-j           | 7.25c-g            |
|                    | 7.5                           | 3.6k-m             | 5.87 g-i           | 8.17a-d            |
| *Eremurus*         | 10                            | 2.99k-n            | 5.44 h-j           | 8.12a-d            |
|                    | 12.5                          | 2.6 l-n            | 3.94 j-l           | 6.1 g-h            |
|                    | 7.5                           | 2.85 l-h           | 7.88b-f            | 9.62a              |
| Tragacanth +*Eremurus* | 10                           | 3.54k-m            | 6.37 f-h           | 8.73a-c            |
|                    | 12.5                          | 3.47k-m            | 7.02d-g            | 8.04b-e            |

Means followed by different letters in each column indicate significant difference at p < 0.05 (LSD test)
Fruit firmness

With increasing storage time, the fruit firmness decreased (Table 2). The measurements showed that after 45 days, with increasing the concentration of tragacanth and Eremurus from 7.5 to 12.5 g L\(^{-1}\), fruit firmness increased significantly and reached the highest value at 12.5 g L\(^{-1}\) treatment (Table 2).

**Table 2.** Effect of tragacanth and *Eremurus* concentrations on the firmness (N) of sweet cherry fruits cv. ‘Takdaneh Mashhad’ during storage time.

| Treatment                   | Concentration (g L\(^{-1}\)) | Storage time (day) |
|-----------------------------|------------------------------|--------------------|
|                             | 0 | 15 | 30 | 45 |
| Control                     | 0 | Sa | 3.03 g | 2.1i-j | 1 l |
| Tragacanth                  | 7.5 | Sa | 3.5e | 3.03 g | 1.2 l |
|                             | 10 | Sa | 4.3b-c | 3.3e-g | 1.6k |
|                             | 12.5 | Sa | 4.6b | 4.3b-d | 2.2i-j |
| Eremurus                    | 7.5 | Sa | 3.5e-f | 2.6 h | 0.9 l |
|                             | 10 | Sa | 4.2c-d | 3.3e-g | 1.2 l |
|                             | 12.5 | Sa | 4.3b-d | 3.9d | 2.3h-j |
| Tragacanth + Eremurus      | 7.5 | Sa | 3.1f-g | 2.03 j | 0.9 l |
|                             | 10 | Sa | 3.4e-g | 2.5 h-i | 1 l |
|                             | 12.5 | Sa | 4.1c-d | 3.2e-g | 0.9 l |

Means followed by different letters in each column indicate significant difference at p < 0.05 (LSD test)

**Figure 1.** Effect of tragacanth and *Eremurus* treatments on the weight loss of sweet cherry fruits cv. ‘Takdaneh Mashhad.’

**Fruit Firmness**

**Soluble Solids Content (SSC)**

Based on the results, the amount of soluble solids increased during storage (Table 3). The highest soluble solids content was observed in the control treatment. All treatments significantly reduced the SSC compared to the control, and this factor decreased with increasing concentrations of treatments, but this decrease was not significant (Table 3).

**TA**

The titratable acidity decreased over time during shelf life (Table 4). Among the treatments, the two upper levels of the tragacanth and *Eremurus* treatments were able to significantly increase the total acid compared to control, also these coating treatments to some extent prevent the reduction of total acid during storage period. But the combination of tragacanth and Eremurus regardless of concentration, prove to be much less successful in TA reduction during storage (Table 4).
Decay Index

During storage periods, the decay rate increased (Table 5). The results showed the highest rate of fungal decay in the control treatment. All coating treatments reduced fungal decay compared to the control treatment, significantly, but there was no significant difference between concentration levels of treatments (Table 5).

Total Phenolics

The measurements in this study showed that the total phenolics of fruits decreased significantly during storage period (Figure 2). But total phenolics content did not change significantly in different treatments.

Polyphenol Oxidase Enzyme Activity (PPO)

Polyphenol oxidase activity increased during storage time (Table 6). The highest level of tragacanth and Eremurus treatments were able to significantly decrease the PPO enzyme content compared to the control. All concentration levels of the combination treatments and the control treatment showed the highest PPO enzyme (Table 6).
Table 5. Effect of tragacanth and *Eremurus* concentrations on the decay index (%) of sweet cherry fruits cv. ‘Takdaneh Mashhad’ during storage time.

| Treatment          | Concentration (g L⁻¹) | 0     | 15    | 30    | 45    |
|--------------------|-----------------------|-------|-------|-------|-------|
| Control            | 0                     | 0.2f-h| 1.68d | 2.6a  |       |
| Tragacanth         | 7.5                   | 0.18g-h| 0.36f |       |       |
| Eremurus           | 7.5                   | 0.14h-i| 0.33f-g|      |       |
| Tragacanth +Eremurus| 10                   | 0.31f-g|       |       |       |
|                    | 12.5                  | 0.23f-h| 0.36f |       |       |
|                    | 7.5                   | 0.24f-h| 0.36f |       |       |
|                    | 10                   | 0.14c-d| 2.14b |       |       |
|                    | 12.5                  | 0.28f-h| 0.36f |       |       |
| Means followed by different letters in each column indicate significant difference at p < 0.05 (LSD test) |

Figure 2. Effect of storage time on the total phenolics content of sweet cherry fruits cv. ‘Takdaneh Mashhad.

**Vitamin C**

Vitamin C decreased during storage time (Table 7). The two high levels of tragacanth and *Eremurus*, (10 and 12.5 g L⁻¹) resulted in more vitamin C and increased about 30% vitamin C compared to control. The lowest vitamin C was observed in the control and combination of tragacanth and *Eremurus* treatments (Table 7).

**Fruit Edible Quality**

During storage period, edible quality of fruits decreased (Table 8). At the start of the experiment fruit-edible quality was completely similar at all treatments. The results showed that with using or not using coating materials, fruit-edible quality was reduced during the storage period. But the slope of decrease in fruit-edible quality in control and tragacanth + *Eremurus* treatments was more than other treatments, maybe it happened due to the flaking early in tragacanth + *Eremurus* combination treatments during the storage time.
Table 6. Effect of tragacanth and *Eremurus* concentrations on the polyphenol oxidase (unit/mg enzyme extract) of sweet cherry fruits cv. ‘Takdaneh Mashhad’ during storage time.

| Treatment         | Concentration (g L⁻¹) | Storage time (day) |
|-------------------|-----------------------|--------------------|
|                   | 0                     | 15                 | 30     | 45     |
| Control           | 856.67p               | 1004.33 h-l        | 1214.67e | 1531.33a-c |
|                   | 856.67p               | 1006.67 h-k        | 1204.67e | 1474.33c  |
| Tragacanth        | 10                    | 885.67 n-p         | 948.67k-n | 1182.67e-f  |
|                   | 12.5                  | 921.33 m-p         | 935.67k-n | 1068.33 g-h  |
|                   | 7.5                   | 860.33 o-p         | 1001 h-l  | 1209.33e | 1476b-c |
| *Eremurus*        | 10                    | 905.33 m-p         | 962.33 j-m | 1112.67f-g  |
|                   | 12.5                  | 933.33 l-o         | 881 n-p   | 1022.67 h-j | 1195e  |
|                   | 7.5                   | 896.33 m-p         | 1053.67 g-i | 1200.67e   |
| Tragacanth +*Eremurus* | 10          | 896.33 m-p       | 995 f-k   | 1217e     | 1557.67a |
|                   | 12.5                  | 857.67 d-p         | 1024 h-j  | 1245e     | 1547.67a-b |

Means followed by different letters in each column indicate significant difference at p < 0.05 (LSD test)

Table 7. Effect of tragacanth and *Eremurus* concentrations on the vitamin C (mg/100⁻¹ fw) of sweet cherry fruits cv. ‘Takdaneh Mashhad’ during storage time.

| Treatment         | Concentration (g L⁻¹) | Storage time (day) |
|-------------------|-----------------------|--------------------|
|                   | 0                     | 15                 | 30     | 45     |
| Control           | 28.5a-b               | 10.6 l-p           | 8.54o-p | 8.71o-p |
|                   | 27.1a-c               | 17.1e-i           | 13.9i-m | 11.7k-o |
| Tragacanth        | 30.7a                 | 19.1d-h           | 14.6i-l | 13.1i-n |
|                   | 28.7a-b               | 23.2c-d           | 14.4i-l | 15.2h-k |
|                   | 26.8a-c               | 15.9 f-k          | 13.9i-m | 12.1j-o |
| *Eremurus*        | 28.4a-b               | 20.4d-e           | 13.8i-m | 16.2e-j |
|                   | 28.4a-b               | 20.1d-f           | 19.5d-g | 15.9f-j |
|                   | 26.22b-c              | 14.5i-l          | 9.9 m-p  | 7p      |
| Tragacanth +*Eremurus* | 25.4b-c       | 15.8 g-k           | 9.3 n-p  | 9.22 n-p |
|                   | 28.7a-b               | 15.8 f-k          | 10.9 l-p | 9.99 m-p |

Means followed by different letters in each column indicate significant difference at p < 0.05 (LSD test)

**Fruit Surface Color**

In general, with the increasing of storage time, the ∆E parameter decreased. The highest level of tragacanth and *Eremurus* treatments (12.5 g L⁻¹) significantly increased the ∆E compared to the control (Table 9).

**Discussion**

When the fruit is harvested, it stops receiving water from the mother plant and immediately begins to lose water by transpiration and this loss accounts for 97% of the total weight loss in fruit, while weight loss from respiration is considered negligible (Díaz-Pérez et al., 2007; Maftoonazad et al., 2008). In this research the highest fruit weight loss was observed in the control treatment, and all the concentrations of tragacanth and *Eremurus* reduced the fruit weight loss compared to uncoated fruits. This result of fruit weight loss was in line with Jahanshahi et al. (2018) and they found that different concentrations of tragacanth prevented fruit weight loss of apple during storage period so that weight loss in control treatment was eight times greater than 10 g L⁻¹ tragacanth treatment in ‘Golden Delicious,’ other tragacanth treatments also prevented weight loss (Jahanshahi et al., 2018). Chitosan could improve the fruit quality of sweet cherry and the least weight loss was found in chitosan treatment comparing to control treatment (Tokath and Demirdöven, 2020). Postharvest weight loss in fruits and vegetables is usually caused by water loss through transpiration. These water losses can cause the product to wilt and shrink and reduce its marketability. Some researches showed that pineapple, apple (‘Granny Smith’ cultivar) and cherry (‘Starking’ cultivar) coated with *Aloe vera* gel showed significantly lower
Table 8. Effect of tragacanth and *Eremurus* concentrations on the edible quality of sweet cherry fruits cv. 'Takdaneh Mashhad' during storage time.

| Treatment          | Concentration (g L\(^{-1}\)) | Storage time (day) |
|--------------------|-------------------------------|-------------------|
|                    | 0                             | 15    | 30    | 45    |
| Control            | 0                             | 5a    | 2.2d-e | 1.3 f-g | 1.1 g |
|                    | 7.5                           | 5a    | 2.5c-e | 1.67 f-g | 1.1 g |
| Tragacanth         | 10                            | 5a    | 3.57b  | 1.9 f  | 1.1 g |
|                    | 12.5                          | 5a    | 3.8b   | 2.1d-e | 1.5 f-g |
|                    | 7.5                           | 5a    | 2.6c-d | 1.6 f-g | 1.7e  |
| *Eremurus*         | 10                            | 5a    | 3.0b   | 1.9 f  | 1.1 g |
|                    | 12.5                          | 5a    | 3.7b   | 2.1d-e | 1.5 f-g |
|                    | 7.5                           | 5a    | 1.7e   | 1.2 f-g | 1.1 g |
| Tragacanth +*Eremurus* | 10                        | 5a    | 2.2d-e | 1.2 f-g | 1.1 g |
|                    | 12.5                          | 5a    | 2.4c-e | 1.2 f-g | 1.1 g |

Means followed by different letters in each column indicate significant difference at \( p < 0.05 \) (LSD test)

Table 9. Effect of tragacanth and *Eremurus* concentrations on ΔE of sweet cherry fruits cv. 'Takdaneh Mashhad' during storage time.

| Treatment          | Concentration (g L\(^{-1}\)) | Storage time (day) |
|--------------------|-------------------------------|-------------------|
|                    | 0                             | 15    | 30    | 45    |
| Control            | 0                             | 5a    | 2.78 h-i | 1.88 n | 1.01p-r |
|                    | 7.5                           | 5a    | 3.4e   | 2.8 h  | 1.03p-q |
| Tragacanth         | 10                            | 5a    | 3.71c-d | 3.1 g  | 1.3o   |
|                    | 12.5                          | 5a    | 4.3b   | 3.8e   | 2.5k-l |
|                    | 7.5                           | 5a    | 3.2 g  | 2.5 l  | 0.94 r |
| *Eremurus*         | 10                            | 5a    | 3.48e  | 2.7i-j | 0.98p-r |
|                    | 12.5                          | 5a    | 3.68d  | 3.33 f | 2.18 m |
|                    | 7.5                           | 5a    | 2.5k-l | 1.05p  | 1.05p  |
| Tragacanth +*Eremurus* | 10                        | 5a    | 3.14 g | 2.56k  | 1.02p-q |
|                    | 12.5                          | 5a    | 3.47e  | 2.67 j | 0.96q-r |

Means followed by different letters in each column indicate significant difference at \( p < 0.05 \) (LSD test)

weight loss percentage than control samples (Adetunji et al., 2012; Ergun and Satici, 2012; Martínez-Romero et al., 2006). The gas exchange and loss of water of fruits is usually controlled by the outer skin. The coatings prevent water from getting out of the skin and also represent a barrier to oxygen, which results in a better preservation of quality (Arowora et al., 2013).

The results of this study in fruit firmness are in agreement with the founding of other researchers (Etemadipoor et al., 2019; Hernández-Muñoz et al., 2006; Jahanshahi et al., 2018; Martínez-Romero et al., 2006; Valverde et al., 2005). Martínez-Romero et al. (2006) showed that *Aloe vera* gel reduces water loss and preserves cherry fruit weight and as a result lower weight loss increases fruit firmness. *Aloe vera* gel decreases the activity of cell wall degrading enzymes (polygalacturonase, pectin methyl esterase and xylanase). Hernández-Muñoz et al. (2006) had a similar report about the effect of strawberry fruit immersion in chitosan and calcium on fruit firmness. *Aloe vera* gel-treated grapes retained their firmness 50% more than control grapes after 21 days of storage (Valverde et al., 2005).

The high increase of soluble solids in control fruits is due to the breakdown of cell wall polysaccharides and their conversion to soluble sugars. Any factor that prevents or decreases cell wall breakage prevents an unusual increase of SSC (Salunkhe et al., 1974). Increase of SSC is also due to water loss what cause higher concentration of total soluble solids. Our results are consistent with the results of previous researches (Khorram et al., 2017; Etemadipoore et al., 2019). In one study, researchers found that *Aloe vera* gel coating has a significant effect on the soluble solids content of apple (Granny Smith) and sweet cherry (‘Starking’ cultivar). Increasing the concentration of *Aloe vera* coating prevents water loss that would cause higher concentration of SSC in fruit and also may be
due to the atmospheric conditions modified by the Aloe vera gel coating, which reduces respiration and as a result metabolism of SSC such as sugars and organic acids are reduced (Ergun and Satici, 2012; Martinez-Romero et al., 2006).

In one research, the tragacanthen coating prevented the increasing of SSC during storage. But by increasing the concentration of tragacanthen from 10 to 15 g L\(^{-1}\), the soluble solids concentrations of apple fruits increased so that there was no significant difference with the control sample. It was because of 15 g L\(^{-1}\) tragacanthen coating treatment was scaly and lost its integrity. Tragacanthen coating also retained SSC better in ’Golden Delicious’ than ’Red Delicious.’ However, during storage time SSC in both cultivars increased (Jahanshahi et al., 2018).

TA results in this study, are in agreement with previous studies (Jahanshahi et al., 2018; Valverde et al., 2005). Aloe vera gel-treated grapes significantly retained total acid compared to control grapes (Valverde et al., 2005). The reduction of total acid in control fruits is higher than in coated fruits associated with higher respiration of these fruits, which results in the decomposition of total acid. These acids serve as substrates for enzymatic activities such as respiration and preservation of total acid in coated fruits can be lower due to low oxygen permeability and lower respiration rate that prevent oxidation of organic acids (Yaman and Bayoudurlu, 2002).

For decay index of fruits, it was reported that the lowest microbial population was observed in cherries (’Starking’ cultivar) treated with Aloe vera gel during 30 days storage at 1°C. Some Aloe vera gel compounds, such as saponins have antifungal properties and can be responsive to antibacterial activity (Martinez-Romero et al., 2006). At different concentrations of tragacanthen, the growth and expansion of any external microorganisms on the surface of apple fruit were controlled (Jahanshahi et al., 2018). The possible mechanism of the antifungal effect of herbal essense is not well understood, but some findings suggest that the antimicrobial effect of them may be attributed to their hydrophobicity that by binding to proteins of microorganism cell membrane releases lipids and polysaccharides and disrupts the physical structure of the membrane, resulting in the breakdown and death of microorganism cells (Martinez-Romero et al., 2006; Serrano et al., 2006; Valverde et al., 2005).

PPO activity decreases at low pH, so any factor that preserves organic acids and low pH will decrease PPO activity (Kang and Yu, 2003). Since chitosan and CaCl\(_2\) alone can inhibit PPO activity, so their combination can increase their effects. PPO activity increased during peach fruit storage and this interaction was higher in control fruits, but 1% chitosan+ 0.5% calcium chloride treatment had more beneficial effect than chitosan treatment and caused slow increase of PPO (Kang and Yu, 2003)

During the storage time, the ascorbic acid, one of the important antioxidants, is reduced because of its use as an electron donor to oxidants to neutralize free radicals (Smirnoff, 1995). Ascorbic acid (vitamin C) is an important nutritional quality parameter in fruits and vegetables that is sensitive to degradation during storage (Bower et al., 2003). This result is in agreement with previous researches. Aloe vera gel-treated cherry fruits at the end of storage time had higher levels of ascorbic acid compared to control fruits, which may be due to higher antioxidant capacity in the treated fruits (Martinez-Romero et al., 2006). In another research, Aloe vera gel coating improves fruit tissue and maintains firmness, thereby reduces wound and other physical damage and caused the accumulation of vitamin C in plant cells (Cordenunsi et al., 2005). Kang and Yu (2003) stated that 1% chitosan + 0.5% calcium chloride and polyethylene coating along with intermittent heating treatment, significantly restricted the activity of peroxidase and polygalacturonase enzymes and thus resulted in preserved vitamin C in peach fruit (Kang and Yu, 2003).

The results of the edible quality were consistent with previous studies (Jahanshahi et al., 2018). Tragacanth coating by glossing the surface of the fruit attracted more consumer attention and also prevented the growth and spread of pathogens by creating a protective layer on the fruit surface, which further increased product acceptance for consumers (Jahanshahi et al., 2018). In agreement with our results, the brightness parameter of Sweet cherry (’Starking’ cultivar) coated with Aloe vera gel for 16 days at 1°C was increased and their difference with control samples was significant, so that Aloe vera gel caused brilliance in sweet cherry fruit (Martinez-Romero et al., 2006).
Conclusion

Tragacanth and *Eremurus* coating treatments improved the quality of the sweet cherry fruits cv. 'Takdaneh Mashhad' during 45 days of storage. These coatings by reducing the evaporation of water, maintained weight and marketability, significantly. Among the treatments 12.5 g L⁻¹ of tragacanth and *Eremurus* had the highest effect on maintaining fruit firmness and acidity, the lowest weight loss, vitamin C reduction and SSC increase, and the least skin color change. Although 7.5 and 10 g L⁻¹ tragacanth and *Eremurus* treatments improved fruit characteristics compared to the untreated fruits but did not appear to provide a suitable coating on the fruit. The combination treatment obtained from tragacanth + *Eremurus* at all used concentrations showed very poor results compared to the control due to the flaking early during the storage time.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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