

## Extending the Shelf life of Apricots by Using Gum Tragacanth-Chitosan Edible Coating

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### ABSTRACT

Formulation of an edible coating based on gum tragacanth and chitosan was optimized for fresh apricots by Response Surface Methodology (RSM). The effects of the concentration of gum tragacanth and chitosan (independent variables) on soluble solids content, weight loss, titratable acidity, pH, reducing sugar, moisture content, and firmness (response variables) were studied. The results showed that the obtained RSM models were fitted for all response variables, except for soluble solids content and titratable acidity. Gum tragacanth and chitosan treatments significantly decreased the weight loss of the apricots during storage. The firmness of apricots was increased at higher concentrations of gum tragacanth. The pH of the apricots was lower at lower concentrations of gum tragacanth and chitosan. This work showed that the coating could improve apricot firmness and stability in terms of weight loss, pH, and moisture content during storage, and increase the commercial value of the product. To meet the desirable properties, the ideal concentrations of gum tragacanth and chitosan in the coating were 1.02 and 0.33% (w/v), respectively.

**Keywords:** *Prunus armeniaca* L., Fruit postharvest, Fruit storage, Response surface methodology.

### INTRODUCTION

*Prunus armeniaca* L. (Apricot) is from *Prunus* species, which belongs to the Rosaceae family. Apricot fruit, which may be used as fresh, dried or processed, is important in human nutrition. Apricots are rich in minerals such as potassium, copper, manganese, magnesium, and phosphorous. Vitamin precursors, especially carotene, are also found in apricots (Haciseferogullari *et al.*, 2007).

In the past two decades, edible coating applications have been the subject of many researches. These food grade materials, which are consumed as part of the product, may extend postharvest storage life of fruits by retarding ripening and reducing physico-

chemical changes. Polysaccharides are widely applied in edible coating formulations, among which alginate, chitosan, gum Arabic and methylcellulose are more investigated (Riva *et al.*, 2020).

Gum Tragacanth (GT) is extracted by cutting the branches of Asiatic species of *Astragalus* (*Leguminosae*). The two principal fractions of gum tragacanth are tragacanthin and bassorin, which are water soluble and non-water-soluble fractions, respectively (Azarikia and Abbasi, 2010). The ratio of Tragacanthin and bassorin of GT is strongly related to the variety (Gavligi *et al.*, 2013). Gum tragacanth is extensively used as a natural thickener and emulsifier in the food and drug industries. Due to its high stability in a broad range of pH and temperature, the consumption of

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gum tragacanth has greatly increased (Mohamadnia *et al.*, 2008). Gum tragacanth is also a nontoxic and biocompatible natural polymer (Otady *et al.*, 2005).

Chitosan has many uses in the food industry. This high molecular weight polysaccharide is a product of chitin deacetylation. Chitosan could theoretically be used in fields of agriculture and food. Many researchers have used it in the formulation of edible coatings or films, due to its antimicrobial, antifungal, biocompatibility and non-toxicity properties (Jayakumar *et al.*, 2005; Prabakaran and Mano, 2006). It has been proved that the shelf life of fruits could be extended by application of chitosan (Chien *et al.*, 2007; Hong *et al.*, 2012; Poverenov *et al.*, 2014). Chitosan expanded the post-harvest storage time and controlled decay for mangoes (Zhu *et al.*, 2008) strawberries (Wang and Gao, 2013) and tomatoes (Badawy and Rabea, 2009).

Morsy and Rayan (2019) investigated the storage life of apricots coated with different edible coatings, including alginate, chitosan and gellan gum. Edible coating has also been used with antioxidant to extend the shelf life of table grapes (Baraiya *et al.*, 2016).

Apricots have a short shelf life, and their losses during storage are considerable due to their susceptibility to decay. They should be sold within a short time after harvest to avoid spoilage. The purpose of this study was to extend the shelf life of apricots during cold storage, so that apricots could be available for a longer time and the losses would be reduced.

## MATERIALS AND METHODS

Apricot fruits (*Prunus armeniaca* L.) were kindly provided by a local producer in Shahrood, Iran. The apricots were kept at 4°C until use. Chitosan (Sigma-Aldrich Co., Steinheim, Germany) and gum tragacanth (local medical market in Mashhad, Iran) were applied as the main

edible component, and glycerol (Sigma-Aldrich Co., Steinheim, Germany) was used as the plasticizer.

### Preparation of Edible Coating Formulations

The concentrations of gum tragacanth and chitosan were selected based on primary tests (data not shown). Thirteen edible coating formulations were prepared by dissolving gum tragacanth (0, 0.75 and 1.5%, w/v) in 1,000 mL distilled water at 40°C for 10 minutes. The chitosan (0, 0.5 and 1%, w/v) was dissolved in 1.0% (v/v) lactic acid by agitating for 10 hours at 20°C. Then, Glycerol was added at the constant concentration (1% w/v). The treatment levels (different formulations) are shown in Table 1.

### Coating Application

About 25-30 apricots were dipped into 1,000 mL of the ediblecoating formulations for 2 minutes and then drained. The control samples were immersed in distilled water. The treated and control apricots were allowed to dry for 3 hours at ambient conditions (25±1°C; 70±10% RH), during which a thin layer of edible coating was created on the surface of the apricots. Then, the coated and control samples were stored for 28 days at 4°C and 75% RH. Sampling was carried out weekly (7, 14, 21, and 28 days of storage) and the effectiveness of the coating in delaying physicochemical changes of the samples was evaluated, compared to uncoated samples.

### Weight Loss

Weight loss was evaluated according to Duan *et al.* (2011) by weighting the samples with a Mettler AE200 precision balance at the start of storage and at other sampling

times. The weight loss percentage was calculated by the following Equation (1):

$$\text{Weight loss\%} = \frac{IW - FW}{IW} \times 100 \quad (1)$$

Where, IW is the Initial fruit Weight and FW is the Final fruit Weight after storage.

### Soluble Solids Content (SSC)

Soluble Solids Content (SSC) in the fruit juice was measured by a Model PAL-1 digital refractometer (Atago, Tokyo, Japan) at 20°C and expressed as the percentage of soluble solids (°Brix).

### Titrateable Acidity

Titrateable Acidity (TA) of the samples was determined according to the method of Bassetto *et al.* (2005). For this purpose, 90 mL of distilled water was added to 10 grams of the crushed fruit and titrated with 0.1N sodium hydroxide to pH 8.1. The result was expressed as the percentage of citric acid.

### Moisture Content

The moisture content of the fruits was obtained according to Ziaolhagh (1999) with some modifications. About 5 grams of each sample was weighed in special containers and dried in an oven at 105 °C for about 6 hours to reach constant weight. The amount of moisture was calculated according to the weight difference based on Equation (2).

$$\text{Moisture Content} = \frac{X_1 - X_2}{M} \times 100 \quad (2)$$

Where,  $X_2$  is the sample weight with container after drying,  $X_1$  is the sample weight with the container before drying, and M is the initial sample weight.

### pH

The apricots were crushed and homogenized for 1 minute at high speed using a hand-held blender. The pH of the

puree was measured by a calibrated Metrohm pH meter (Abedian, *et al.* 2016).

### Reducing Sugar Content

The 3, 5-dinitrosalicylic acid colorimetric method was used to measure the reducing sugar content. Five g of the homogenized apricot puree (made by a Moulinex LM850 home mixer) was suspended in 50 mL of distilled water for 30 minutes and then filtered. One mL of the reagent, 3, 5-dinitrosalicylic acid solution was added to 1 mL of the filtered sample and its absorbance was read by a spectrophotometer (Jenway 6800, Germany) at 540 nm. The content of reducing sugars was determined following the procedure described by Miller (1959).

### Firmness

A texture analyzer (TA-TX2i, Stable Micro System Ltd., England) was used to evaluate the firmness of the fruits. A 2 mm round stainless steel probe, at a speed of 1 mm s<sup>-1</sup> was used for penetration test of the samples and the maximum required force (N) for the probe to penetrate the sample was recorded. Three measurements at the stem end, middle of the fruit and blossom end were taken from each fruit and the results were averaged.

### Experimental Design and Statistical Analysis

Design-Expert 7 statistical software was used to analyze the results by Response Surface Methodology (RSM) based on a central composite design (face-centered) of 13 runs with five replications at the central point. The concentrations of gum tragacanth (0-1.5%) and chitosan (0-1%) were used as independent variables. The design variables with actual and coded levels are shown in Table 1. Gum tragacanth-chitosan based edible coating formulations were optimized

**Table 1.** Central composite face center design for the independent variables (actual and coded levels).

| Run | Independent variables     |                  |                           |                  |
|-----|---------------------------|------------------|---------------------------|------------------|
|     | Actual levels             |                  | Coded levels              |                  |
|     | Gum tragacanth<br>(% w/v) | Chitosan (% w/v) | Gum tragacanth<br>(% w/v) | Chitosan (% w/v) |
| 1   | 1.5                       | 0                | 1                         | -1               |
| 2   | 0.75                      | 0.5              | 0                         | 0                |
| 3   | 0.75                      | 0.5              | 0                         | 0                |
| 4   | 1.5                       | 0.5              | 1                         | 0                |
| 5   | 0.75                      | 0.5              | 0                         | 0                |
| 6   | 0.75                      | 0.5              | 0                         | 0                |
| 7   | 0.75                      | 1                | 0                         | 1                |
| 8   | 0.75                      | 0.5              | 0                         | 0                |
| 9   | 1.5                       | 1                | 1                         | 1                |
| 10  | 0.75                      | 0                | 0                         | -1               |
| 11  | 0                         | 1                | -1                        | 1                |
| 12  | 0                         | 0                | -1                        | -1               |
| 13  | 0                         | 0.5              | -1                        | 0                |

using RSM. The effects of the gum tragacanth ( $X_1$ ) and chitosan concentrations ( $X_2$ ) on the response variables (firmness, weight loss, and moisture content) were evaluated. The following second-order polynomial model was applied:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_{12}X_1X_2 + b_{11}X_1^2 + \dots + b_{22}X_2^2 \quad (3)$$

Where,  $Y$  is the response variable;  $b_0$  is the intercept;  $b_1$ – $b_{22}$  are regression coefficients obtained by calculating the observed experimental values of  $Y$ ; and  $X_1$ – $X_2$  are the coded levels of independent variables.

## RESULTS AND DISCUSSION

The initial values for soluble solids content, acidity, moisture content, pH and reducing sugars of apricots at the start of storage were 21%, 0.511%, 82.43%, 4.78, and 11.2 g 100 mL<sup>-1</sup>, respectively.

Experimental and predicted results of apricot dependent variables are shown in Table 2. Each response was assessed as the function of main, quadratic and interaction effects of gum tragacanth ( $X_1$ ) and chitosan ( $X_2$ ) concentrations. Model analysis, lack of fit and coefficient of determination were used to determine the adequacy of the

models. Relatively high coefficients of determination ranging from 0.78 to 0.99 with no significant ( $P > 0.05$ ) lack of fit were found for the final reduced models (Table 3). These indicate that the response surface models were significantly fitted for all the studied responses, except for titratable acidity, total soluble solids and reducing sugar. As shown in Table 4, both gum tragacanth and chitosan concentrations had significant effects on the weight loss, pH, moisture content and firmness of apricots. The main effect of gum tragacanth concentration contributed more significantly to the fruit weight loss, pH and firmness, whereas chitosan had a more prominent effect on the decreases in moisture content and pH (Table 4).

### Firmness

Fruit firmness is critical in overall product acceptance by consumers. The composition and mechanical strength of the cell wall are important factors that, when changed, cause firmness losses throughout fruit on tree ripening or later harvesting. Hydrolyzing enzymes activity in the cell wall of climacteric fruits is increased due to ethylene production (Valero and Serrano,

**Table 2.** Decoded experimental design matrix used (CCDR) as a function of independent variables: Gum Tragacanth (GT) concentration and chitosan concentration; Experimental (E) and Predicted (P) results of apricot Soluble Solids Content (SSC), Weight Loss (WL), pH, Moisture Content (MC), Titratable Acidity (TA), Reducing Sugar (RS) and firmness.

| Run | Independent variable |                     | Response variable |      |         |       |        |       |        |       |      |      |                              |       |        |      |  |  |
|-----|----------------------|---------------------|-------------------|------|---------|-------|--------|-------|--------|-------|------|------|------------------------------|-------|--------|------|--|--|
|     | GT (%)<br>w/v        | Chitosan (%)<br>w/v | Firmness (N)      |      | SSC (%) |       | WL (%) |       | MC (%) |       | pH   |      | RS (g 100 mL <sup>-1</sup> ) |       | TA (%) |      |  |  |
|     |                      |                     | E                 | P    | E       | P     | E      | P     | E      | P     | E    | P    | E                            | P     | E      | P    |  |  |
| 1   | 1.5                  | 0                   | 0.56              | 0.53 | 22.1    | 22.65 | 31.73  | 31.20 | 23.5   | 23.52 | 5.11 | 5.10 | 12.5                         | 11.35 | 0.37   | 0.40 |  |  |
| 2   | 0.75                 | 0.5                 | 0.82              | 0.81 | 22.9    | 23.05 | 22.45  | 25.98 | 22.4   | 20.6  | 5.33 | 5.33 | 10.5                         | 11.33 | 0.24   | 0.31 |  |  |
| 3   | 0.75                 | 0.5                 | 0.82              | 0.81 | 22.0    | 23.05 | 27.40  | 25.98 | 23.7   | 20.6  | 5.34 | 5.33 | 13.33                        | 11.33 | 0.29   | 0.31 |  |  |
| 4   | 1.5                  | 0.5                 | 0.64              | 0.70 | 20.5    | 22.12 | 25.29  | 25.84 | 18.8   | 18.33 | 5.43 | 5.44 | 10                           | 10.79 | 0.33   | 0.29 |  |  |
| 5   | 0.75                 | 0.5                 | 0.80              | 0.81 | 22.0    | 23.05 | 26.81  | 25.98 | 17.5   | 20.6  | 5.33 | 5.33 | 13.4                         | 11.33 | 0.40   | 0.31 |  |  |
| 6   | 0.75                 | 0.5                 | 0.89              | 0.81 | 22.1    | 23.05 | 26.63  | 25.98 | 19     | 20.6  | 5.33 | 5.33 | 11.76                        | 11.33 | 0.26   | 0.31 |  |  |
| 7   | 0.75                 | 1                   | 0.79              | 0.77 | 23.2    | 22.79 | 27.53  | 27.80 | 18.7   | 16.63 | 5.51 | 5.51 | 12.5                         | 12.49 | 0.38   | 0.35 |  |  |
| 8   | 0.75                 | 0.5                 | 0.72              | 0.81 | 22.6    | 23.05 | 26.7   | 25.98 | 17.1   | 20.6  | 5.34 | 5.33 | 10.01                        | 11.33 | 0.25   | 0.31 |  |  |
| 9   | 1.5                  | 1                   | 0.66              | 0.63 | 22.0    | 22.23 | 31.17  | 31.20 | 10.6   | 11.05 | 5.75 | 5.75 | 13.33                        | 12.95 | 0.32   | 0.33 |  |  |
| 10  | 0.75                 | 0                   | 0.63              | 0.62 | 23.2    | 23.95 | 28.95  | 28.83 | 23.7   | 22.49 | 5.11 | 5.12 | 9.09                         | 11.01 | 0.49   | 0.43 |  |  |
| 11  | 0                    | 1                   | 0.42              | 0.46 | 24.1    | 20.98 | 31.08  | 31.20 | 11.7   | 13.32 | 5.26 | 5.26 | 12.51                        | 11.35 | 0.30   | 0.33 |  |  |
| 12  | 0                    | 0                   | 0.23              | 0.27 | 23.4    | 22.90 | 34.20  | 34.51 | 11.4   | 12.59 | 5.12 | 5.11 | 11.12                        | 10.33 | 0.37   | 0.41 |  |  |
| 13  | 0                    | 0.5                 | 0.56              | 0.48 | 23.5    | 21.62 | 30.93  | 30.52 | 16.8   | 13.99 | 5.19 | 5.20 | 10.4                         | 11.53 | 0.34   | 0.29 |  |  |

**Table 3.** Regression coefficients,  $R^2$ , adjusted  $R^2$ , probability values and lack of fit for the final reduced models.<sup>a</sup>

| Regression coefficient | TSS (%) | WL (%) | pH     | MC (%) | TA (%) | RS (mg 100 g <sup>-1</sup> ) | Firmness (N) |
|------------------------|---------|--------|--------|--------|--------|------------------------------|--------------|
| Model                  | 1.04    | 7.09   | 972.2  | 5.10   | 1.07   | 0.52                         | 17.88        |
| A                      | 0.28    | 13.58  | 1098.4 | 3.56   | 0.00   | 0.30                         | 16.65        |
| B                      | 1.54    | 0.66   | 2950.4 | 6.53   | 1.85   | 1.90                         | 7.98         |
| AB                     | 0.42    | 2.16   | 792.64 | 5.51   | 0.008  | 0.028                        | 0.48         |
| A <sup>2</sup>         | 2.9     | 5.56   | 5.41   | 6.88   | 0.35   | 0.029                        | 33.26        |
| B <sup>2</sup>         | 0.21    | 6.24   | 5.41   | 0.38   | 3.48   | 0.39                         | 8.74         |
| R <sup>2</sup>         | 0.42    | 0.83   | 0.99   | 0.78   | 0.43   | 0.27                         | 0.92         |
| Regression (P-value)   | 0.46    | 0.01   | 0.0001 | 0.02   | 0.45   | 0.75                         | 0.0007       |
| Lack of fit (P-value)  | 0.87    | 0.97   | 0.08   | 0.55   | 0.43   | 0.36                         | 0.38         |

<sup>a</sup> SSC: Soluble Solids Content, WL: Weight Loss, MC: Moisture Content, TA: Titratable Acidity, RS: Reducing Sugar.

**Table 4.** Significance probability (P-values) of the dependent variables.

| Regression coefficient | A      | B      | AB     | A <sup>2</sup> | B <sup>2</sup> |
|------------------------|--------|--------|--------|----------------|----------------|
| WL <sup>a</sup> (%)    | 0.007  | 0.44   | 0.18   | 0.05           | 0.04           |
| pH                     | 0.0001 | 0.0001 | 0.0001 | 0.05           | 0.05           |
| MC <sup>b</sup> (%)    | 0.101  | 0.037  | 0.051  | 0.034          | 0.55           |
| Firmness (N)           | 0.004  | 0.25   | 0.51   | 0.0007         | 0.02           |

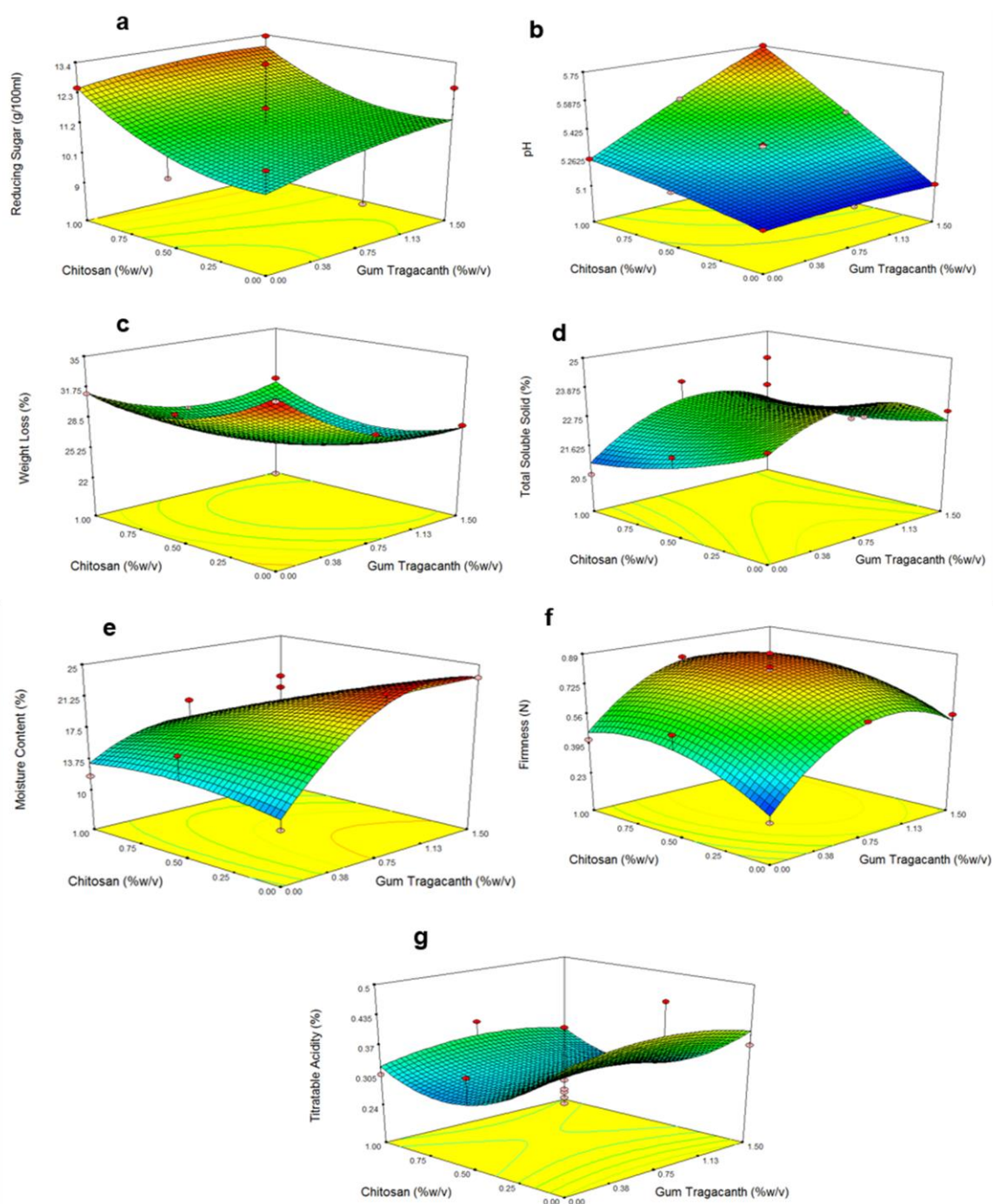
<sup>a</sup> Weight loss, <sup>b</sup> Moisture content. P-value < 0.05 significant and P-value > 0.05 not significant.

2010). Fruit softening can take place by way of two possible mechanisms. The first is related to the decomposition of polymeric carbohydrates that occurs during ripening and that cause weakening of the cell walls. During the early stages, the texture makes the fruit tastier and, finally, fruit softening will occur due to the breakdown of plant structures (Wills *et al.*, 2007). As a matter of fact, carbohydrates are good gas barriers due to their high polarity. Both Chitosan and gum tragacanth are polysaccharides which do not allow oxygen and other non-polar substances to pass through (Lacroix and Le Tien 2005). Application of chitosan and gum tragacanth as surface coatings for apricot was expected to reduce oxygen permeability, and thus to reduce respiration rate. Subsequently, the ripening process and possibly the hydrolysis activities would slow down. This can cause fruit softening. This phenomenon was shown by the positive effect of these coatings on firmness (Figure 1). In contrast to chitosan, gum tragacanth had significant ( $P < 0.05$ ) effects on the

firmness of apricot, which indicates that firmness of apricot fruit was better when gum tragacanth concentrations increased.

Reduction in turgidity of the cells due to water vapour transmission is another mechanism that leads to loss of fruit firmness (Garcia and Barret, 2002). Increase in gum tragacanth concentration made it possible to form a thick layer of coating all over the apricot fruit surface that could decrease moisture loss until the gum tragacanth coating was dried by itself. Dehydration of the thick layer of gum tragacanth coating instead of the fruit resulted in the preservation of acceptable apricot firmness longer (Figure 1).

The concentration of second component of the coating, chitosan, displayed no linear significant change in apricot firmness, but its quadratic effect was positively significant ( $P < 0.05$ ) (Table 4). This result was confirmed by Abedian *et al.* (2018). They evaluated the firmness of apricots coated with alginate and chitosan and indicated that higher concentrations of chitosan make the



**Figure 1.** Effects of chitosan and gum tragacanth concentrations on the reducing sugars (a), pH (b), weight loss (c), soluble solids content (d), moisture content (e), firmness (f), and titratable acidity (g).



apricots firmer than those with lower concentrations.

### Soluble Solids Content (SSC)

Aerobic respiration causes the carbohydrates and other sources of energy to be broken down. Therefore, the sugar content of apricot fruits is reduced during storage. Sugars are the major substrates for respiration (Tseng and Mau, 1999). Total and soluble sugar concentrations in harvested plant products are considered important indicators of post-harvest deterioration (Hammond and Nichols 1975). The concentration of total soluble solids decreased slightly in apricots coated with gum tragacanth (Figure 1). Du *et al.* (1997) showed that respiration of kiwifruit, peach, and Japanese pear was inhibited by the use of chitosan coating. In comparison to the control sample, a lower level of TSS of coated apricot fruit was observed after 28 days of storage at 4°C in the current study, but it was not significant. Martínez-Romero *et al.* (2006) also showed that cherries coated with *Aloe vera* pulp maintains SSC over time. The mechanism of this favorable effect of the coatings is the formation of a barrier against oxygen, which reduces the respiration of fruits. In addition, Yonemoto *et al.* (2002) reported that coating delayed increase of SSC in cherimoya fruit. They attributed it to the inhibitory effect of the coating against oxygen and the lack of oxygen at the surface of the fruit, which inhibits respiration.

### Weight Loss

The analysis of variance for final reduced models (Table 4) showed that only quadratic effects of gum tragacanth and chitosan were significant on weight loss ( $P < 0.05$ ). This quality parameter is really important, since weight loss equals economic loss. Water is lost during transpiration and respiration processes and

this is the main cause of weight loss in fruits and vegetables. The amount of other components that are lost, such as aromas, flavours, and gases (product of respiration) are not considerable (Maguire *et al.*, 2001; Olivas and Barbosa-Cánovas, 2005; Zhu *et al.*, 2008). The principal mechanism of weight loss in fruits is the evaporation of water due to the water vapour pressure gradient at different points (Yaman and Bayoindirli, 2002). Weight loss was enhanced during cold storage for all apricots. However, gum tragacanth and chitosan treatments significantly decreased weight loss for all apricots (Figure 1). Previous studies reported similar results for fresh-cut apricots coated with basil-seed gum (Hashemi, *et al.*, 2017), strawberries coated with chitosan (Azevedo *et al.*, 2014) and apricots coated with chitosan, sodium alginate and whey protein concentrate (Abedian *et al.*, 2018). Bal (2018) showed that chitosan coating effectively reduced respiration rate and weight loss of plums stored at 0-1°C. Epidermal cell layer and cuticle are the natural structures that reduce Transpiration. Hence, edible coatings act as a further layer that covers the stomata and reduces weight loss by decreasing transpiration. It is the primary advantage of edible coatings. Therefore, coating treatments have been used to preserve many fruits, such as apricots, peppers, peaches, sweet cherries, and litchi (Ayranci and Tunc, 2004; Díaz-Mula *et al.*, 2012; Dong *et al.*, 2004; Maftoon Azad *et al.*, 2008). Furthermore, various coating materials have different ability to reduce weight loss, because of different water vapour permeability of the polysaccharides applied in the edible coating (Vargas *et al.*, 2008).

### Moisture Content

In fact, fruits and vegetables have high moisture content, so, weight loss during transportation and storage can be a serious economic factor, especially if the fruits are sold based on weight. In

most vegetables and fruits 5–10% loss in moisture content, cause the products to shrivel due to cellular plasmolysis (Hodges, 2003).

According to Figure 1, both gum tragacanth and chitosan concentrations showed a significant ( $P < 0.05$ ) positive effect (quadratic and linear, respectively) on the moisture content of apricot fruits. Figure 1 illustrates that the coating process caused a delay in the reduction of moisture content during post-harvest storage.

### pH

Generally, an increase of pH values may be associated to apricot spoilage, with the creation of alkaline autolysis compounds (e.g., nitrogenous compounds) (Soares *et al.*, 2013) and the formation of fungal metabolites (Figure 1). Based on our results, the effect of coating process was not significant on control of pH (Table 4). Similar to our results, Ghasemnezhad *et al.* (2010) found no significant difference between the acidity of chitosan-coated apricots. On the contrary, Abedian *et al.* (2018) showed the rising of the acidity of apricots by increasing the concentration of alginate and chitosan in the coating formulation.

### Reducing Sugars

Starch and other storage polysaccharides are broken down to reducing sugars such as glucose as respiration begins in fruits (Irtiza, *et al.*, 2019). As shown in Figure 1, the reducing sugar was increased. The total sugar was increased for uncoated fruits on the 21<sup>st</sup> day of storage with a value of 28.24 mg g<sup>-1</sup>. After that, reducing sugar of the control samples decreased, which was probably because of the rapid ripening of fruits and utilization of sugar (data not shown). For coated fruits, there was a slight increase on the 21<sup>st</sup> day, but a major peak was observed at the 28<sup>th</sup> day of storage. The

reducing sugar percentage is an influential factor for determining the quality of fruits. Moreover, the flavour of a product relates to its total sugar percentage. Consequently, application of the composite coatings may help keep the flavour of fruit for a long period of storage.

### Titrateable Acidity

Reduction of the amount of total acidity during post-harvest storage of fleshy fruits is usual, which is mainly due to the decomposition of organic acids of the respiration metabolism (Díaz-Mula *et al.*, 2009; Gol *et al.*, 2013; Valero and Serrano, 2010). Nevertheless, acidity reductions were varied depending on apricot treatments. Gum tragacanth and chitosan edible coatings delayed acidity increase in apricot fruits with respect to control the apricots (Figure 1). In general, no significant differences were found among treatments. In cold storage, acidity reductions were very low in the control apricots and no considerable impact attributed to edible coating was observed (data not shown). Varasteh *et al.* (2017) also indicated a slight decline in titrateable acidity of chitosan-coated pomegranates stored at 5°C for up to 135 days.

### Optimization and Validation Process

The levels of the independent variables that could give maximum firmness and lowest weight loss on the coated fruits were predicted using the multiple response optimization process. The optimum conditions obtained were 1.02 and 0.39% (w/v) of gum tragacanth and chitosan concentrations, respectively (Table 5). For this optimization study, the chitosan concentration is lower than gum tragacanth in the edible coating. This could be because gum tragacanth is more hygroscopic than chitosan, so, it forms a better barrier to water diffusion between apricot fruit and environment. Thus, a higher concentration



of gum tragacanth was necessary to maintain good properties of the fruit.

## CONCLUSIONS

Coating formulations based on gum tragacanth-chitosan were appropriately used for surface coating of apricots. The higher firmness and moisture and lower weight loss values showed that gum tragacanth and chitosan at the levels of 1.02 and 0.39% (w/v), respectively, were able to extend the shelf-life of apricots. The adequacy of the fitted reduced model also showed that RSM could be used as a tool for predicting coating formulation concentrations.

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## افزایش عمر انباری زردآلو با استفاده از پوشش خوراکی مبتنی بر صمغ کتیرا و کیتوزان

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### چکیده

در این مطالعه، فرمولاسیون پوشش خوراکی صمغ کتیرا و کیتوزان برای پوشش‌دهی زردآلوی تازه با روش سطح پاسخ (RSM) بهینه شد. تأثیر غلظت صمغ کتیرا و کیتوزان (متغیرهای مستقل) بر مواد جامدات محلول، کاهش وزن، اسیدیته قابل تیتر، pH، قندهای احیاکننده، مقدار رطوبت و سفتی زردآلو (متغیرهای وابسته) مورد بررسی قرار گرفت. نتایج نشان داد که مدل‌های RSM به‌دست آمده

به طور معنی داری برای کلیه متغیرهای وابسته (به استثنای مواد جامد محلول و اسیدیته قابل تیتر) مناسب بودند. صمغ کتیرا و کیتوزان به طور معنی داری میزان کاهش وزن زردآلوها را در طی نگهداری کاهش دادند. سفتی زردآلوها با افزایش غلظت صمغ کتیرا افزایش یافت. pH زردآلوها نیز در غلظت‌های پایین تر صمغ کتیرا و کیتوزان کمتر بود. این مطالعه نشان داد که این پوشش می‌تواند سفتی و پایداری زردآلو از نظر کاهش وزن، pH و میزان رطوبت را هنگام نگهداری در سردخانه بهبود بخشد و ارزش تجاری محصول را افزایش دهد. برای دستیابی به خواص مطلوب، بهترین فرمولاسیون ترکیب ۱/۰۲ درصد صمغ کتیرا و ۰/۳۳ درصد کیتوزان به دست آمد.