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A novel edible coating for apple fruits

Behnam Jahanshahi[1], Azam Jafari[2,*], Mohammad Reza Vazifeshenas[3], Jalal Gholamnejad[4]

1, 2, 4 Department of Horticultural Science, Ardakan University, Ardakan, Iran

3, Agricultural and Natural Resources Research Center, Yazd. Iran

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***Corresponding author:**

Department of Horticultural Science, Ardakan University, Postal code 89518-95491, Ardakan, Iran,
E-mail: **ajafari@ardakan.ac.ir**

ABSTRACT

Edible coatings are an environmentally friendly technology that is applied to many products to control moisture transfer, soluble and aromatic materials, gas exchange or oxidation processes. The objective of this research was to study the effect of tragacanth gum at the concentrations of 0, 5, 10, and 15 kg m^{-3} on storage life and edible quality of apple cvs. Red Delicious and Golden Delicious. After applying treatments, the fruits were kept in a cold storage at a temperature of 0±1 °C and relative humidity of 85-95%. The weight reduction, external quality, microbial load, and general acceptability of the samples were evaluated after 0, 30, 60, 90 and 120 days of storage, then compared with uncoated apples. It was found that the tragacanth gum significantly reduced fruit weight loss compared to the control, so that weight reduction in uncoated apples was eight times greater than fruits treated with tragacanth gum at 10 kg m^{-3}. This coating preserved firmness of fruit tissue in storage and prevented the softening and senescent breakdown of apples. The tragacanth gum coating desirably preserved the external quality and improved the microbial load, sensory and external properties of the fruits, preserved quality factors of the apples, and prevented fruit ripening during storage. Among the various treatments, the coating at 10 kg m^{-3} was more effective than the other treatments, maintained fruit juice acidity and pH at desirable levels, and prevented increases in the contents of soluble solids during the storage.

INTRODUCTION

Apple is considered as one of the most consumed fruits in the world. It is consumed in different forms as fresh fruit or as a wide range of industrially processed products. Based on respiration behavior and ethylene production, apple is classified as a climacteric fruit. This means that the metabolic activities and ripening continue after harvesting, thus, making apple fruits highly perishable commodities. Due to its tendency towards fast ripening and texture breakdown, apple is difficult to keep well for a longer period of time. A number of workers have made attempts to enhance the storage life of apple using different substances at the pre or postharvest stages. Postharvest decay during the supply chain has been identified as a major factor causing postharvest loss which could result in a significant economic loss, especially in the fruit marketing chain. Incidences of postharvest diseases may occur during the different stages of the postharvest chain; during harvesting, field handling, packing operations, transportation and storage (Prusky, 2011; Wang et al., 2007).

In recent years, edible films and coating have been considered one technology with great potential to improve the safety of food and to protect it from the influence of external environmental factors, thus increasing its shelf life (Carneiro-da-Cunha et al., 2009; Cerqueira et al., 2011). These natural polymeric polysaccharides have many advantages as compared to synthetic polymers because they are biodegradable, non-toxic, economical and easily available in the environment which is used as edible coatings in various foods (Asnaashari et al., 2016). They can be used as an emulsifier, stabilizer, thickener, and an inhibitor of sugar and ice crystals formation due to their hydrocolloid properties (Farahmandfar et al., 2017; Weiping & Branwell, 2000). For many years the tragacanth gum is used as an efficient hydrocolloid in the food, pharmaceutical, cosmetics, textiles, and leather industries (Balaghi et al., 2011). Tragacanth gum is one of the most popular herbal gum that exudates from the stem of *Astragalus gummifer* (Gentry, 1957). Tragacanth gum consists of two components: Bassorin (insoluble in water and capable of swelling and forming gel) and Tragacanthin (soluble in water and capable of the forming colloid solution), and the following sugar: arabinose, xylose, glucose, fructose, galactose, rhamnose and galacturonic acid (Balaghi et al., 2010; Weiping & Branwell, 2000). So, the aim of this research was to assess the effects of tragacanth gum on the apple fruit characteristics during postharvest cold storage which is performed for the first time in apple.

MATERIALS AND METHODS

Plant materials

Red Delicious and Golden Delicious apple cultivars were used and fruits were acquired from a grower in Semirom County, Esfahan, Iran. Apple fruits were hand-harvested at a commercially mature stage. Apples with defects (e.g., cracks) were discarded and only fruits with healthy outer skins and uniform appearance and size were used. Then healthy fruits were immediately transferred to a cold storage.

Preparation of coating formulation (Tragacanth gum solution)

At this stage, strip-shaped of tragacanth turned into powder using an electric mill and sieved to produce a fine powder. The powdered tragacanth gum at different concentrations (0, 5, 10 and 15 kg m^{-3}) was added gently to the distilled water and then stirring the solution was done to obtain a complete dissolving of the gum.

Application of treatments and experimental design

Fresh fruits were dipped completely into the coating solutions containing 0, 5, 10 and 15 kg m^{-3} tragacanth gum, at room temperature for three minutes. Sterile distilled water was used as the control solution. Following treatments, all fruits were allowed to drain and dried at room temperature to allow a thin film layer to be formed on the fruits. The coated and uncoated (control) fruits were then weighed and packaged in boxes. The fruits were then stored at 0±1 °C and 85-95% relative humidity. The experiment was a factorial in a split plot design with three replications. The main factors were cultivar and tragacanth gum concentration and the sub factor was evaluation time. Fruits were evaluated for their physicochemical and microbiological characteristics at 30-day intervals (after 0, 30, 60, 90 and 120 days of storage).

Physicochemical analyses

Before analyses, fruits were first kept at room temperature for two days and then their characteristics were measured.

Firmness and weight loss

The firmness of apples in each replicate was evaluated by a manual fruit penetrometer (GY3, China). Weight loss was evaluated according to Duan et al. (2011) by weighing all fruits at the beginning of storage (day 0) and at all sampling days. The percentage of weight loss was determined by the following equation (1):

$$\text{Weight loss (\%)} = \frac{Wi - Wf}{Wi} \times 100 \qquad (1)$$

Where Wi is the initial sample weight and Wf is the sample weight.

Titratable acidity (TA), pH, soluble solid content (SSC)

Titratable acidity (TA) was determined using 942.15 AOAC methods (AOAC, 1997), specific for fruit derivate, by measuring the amount of 0.1 mol L^{-1} NaOH. The TA was expressed as a percentage of malic acid per 100 mL fruit juice (AOAC, 2002). The pH value was determined using a pH meter. Juice from the fruit was used to determine the soluble solid content (SSC) using a digital refractometer, standardized with water (AOAC, 2002).

Microbiological evaluations

This experiment was conducted using a completely randomized design with four PDA culture media containing 0, 5, 10, and 15 kg m^{-3} tragacanth gum with three replications. Apples that were infected with blue-green mold collected from the cold storage and 25 mm^2 of infected fruit peel were cut and placed at the center of the Petri dishes containing culture media to assess its ability in controlling the fungal growth. The Petri dishes were placed in an incubator at 24 °C, and the surface areas where fungal masses had grown, were measured and recorded 12 days later.

Statistical analysis

Analysis of variance was carried out using the SAS statistical program (ver. 9.1.3, SAS Institute, Cray, NC) and means for significant treatments separated using LSD test at the significant level ($P<0.05$).

RESULTS AND DISCUSSION

Firmness

According to our results, 10 kg m^{-3} tragacanth gum coating was more effective in firmness retention compared to others and with increasing the storage time the rate of softening increased in fruits (both coated and uncoated) but it was significantly declined in uncoated treatments (Table 1). The firmness retention of apples in both cultivars was the highest at the beginning of the experiment. The firmness is one of the most important physical quality characteristics of fruit during storage (Pasquariello et al., 2013). Fruit tissue is softened by changes in cell wall structure. This is a biochemical process involving pectin and starch hydrolysis due to enzymes including wall hydrolyses. Depolymerization (shortening of chain length of pectin substances) occurs with an increase in pectinesterase and polygalacturonase activities during fruit ripening. In agreement with this finding, banana fruits treated with gum arabic delayed fruit ripening and resulted in firmer fruits (Maqbool et al., 2011).

These results are in agreement with the results reported by many studies which stated that the firmness of fruits treated with edible coatings including *Aloe vera* in cherries (Martinez Romero et al., 2006) and grapes (Valverde et al., 2005), tragacanth and *Aloe vera* (Emamifar & Bavaisi, 2017), starch (Garcia et al., 2012), calcium and chitosan (Hernandez Munoz et al., 2006) and gluten (Tanda-Palmu & Grosso, 2005) in strawberries.

Table 1. Effect of different tragacanth gum concentration on the fruit firmness of coated and uncoated apple cultivars during storage time

Treatments (kg m^{-3})	Cultivar	Time (month)				
		0	1	2	3	4
0	Red Delicious	7.17^{ac}†	5.17^{o}	4.97^{p}	3.83^{r}	3.5^{s}
	Golden Delicious	7.34^{a}	5.94^{j}	5.33^{no}	4.33^{q}	3.93^{r}
5	Red Delicious	7.17^{ac}	6.93^{df}	6.9^{ef}	6.53^{hi}	6.37^{i}
	Golden Delicious	7.3^{a}	6.9^{ef}	6.63^{h}	5.67^{kl}	5.57^{lm}
10	Red Delicious	7.3^{a}	7.1^{bd}	7.1^{bd}	7^{cf}	7^{cf}
	Golden Delicious	7.33^{a}	7.2^{ab}	7.1^{bd}	7.1^{cf}	6.93^{cf}
15	Red Delicious	7.17^{ac}	6.9^{ef}	6.7^{gh}	5.9^{j}	5.4^{mn}
	Golden Delicious	7.3^{a}	7.07^{be}	6.83^{fg}	6.43^{i}	5.77^{jk}

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

Table 2. Effect of different tragacanth gum concentration on the fruit weight loss (%) of coated and uncoated apple cultivars during storage time

Treatments (kg m^{-3})	Cultivar	Time (month)				
		0	1	2	3	4
0	Red Delicious	0^{v}†	1.29^{m}	2.84^{f}	3.52^{d}	1^{b}
	Golden Delicious	0^{v}	2.5^{g}	3.11^{e}	4.4^{c}	5.69^{a}
5	Red Delicious	0^{v}	0.12^{u}	0.44^{qr}	1.04^{n}	1.27^{m}
	Golden Delicious	0^{v}	1.11^{n}	1.66^{k}	1.88^{j}	1.89^{j}
10	Red Delicious	0^{v}	0.09^{uv}	0.15^{tu}	0.25st	0.51^{pq}
	Golden Delicious	0^{v}	0.31^{rs}	0.41^{qr}	0.52^{pq}	0.58^{op}
15	Red Delicious	0^{v}	0.58^{op}	0.63^{o}	1.13^{n}	1.43^{l}
	Golden Delicious	0^{v}	1.58^{k}	1.9^{j}	2.12^{i}	2.27^{h}

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

Table 3. Effect of different tragacanth gum concentration on TA (%) of coated and uncoated apple cultivars during storage time

Treatments (kg m^{-3})	Cultivar	Time (month)				
		0	1	2	3	4
0	Red Delicious	0.25^{j}†	0.23^{k}	0.19^{p}	0.18^{q}	0.16^{r}
	Golden Delicious	0.38^{ab}	0.27^{gh}	0.26^{ij}	0.20^{mo}	0.19^{np}
5	Red Delicious	0.25^{j}	0.26^{ij}	0.25^{ij}	0.23^{k}	0.21^{mn}
	Golden Delicious	0.37^{ad}	0.36^{d}	0.37^{ad}	0.33^{e}	0.29^{f}
10	Red Delicious	0.26^{hg}	0.27^{gi}	0.26^{ij}	0.26^{ij}	0.26^{ij}
	Golden Delicious	0.38^{a}	0.38^{a}	0.38^{ac}	0.37^{cd}	0.37^{bd}
15	Red Delicious	0.26^{ij}	0.25^{ij}	0.22^{lm}	0.19^{op}	0.17^{q}
	Golden Delicious	0.37^{ad}	0.37^{bd}	0.28^{g}	0.27^{gi}	0.22^{kl}

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

Weight loss

As shown in Table 2, 10 kg m-3 coated fruits showed a lower loss ratio of water compared to uncoated ones. Tragacanth gum coating led to a lower weight loss amount in Red Delicious compared to Golden Delicious in all coated and uncoated fruits and then it has a better result on this apple cultivar in preserving water content. In both cultivars, the lowest weight loss was observed in apple fruits that were coated with 10 kg m-3 tragacanth gum and control treatment (uncoated fruits) had the highest weight reduction.

Ergun and Satici (2012), Martinez Romero et al. (2006) and Adetunji et al. (2012) reported that postharvest weight losses in fruits and vegetables usually resulted from water loss through transpiration. Emamifar and Bavaisi (2017) reported that compared with untreated fruits, using *Aloe vera* and tragacanth gum treatment significantly decreased the weight loss in strawberries. Vieria et al. (2016) showed that the coating of blueberry fruits with chitosan-*Aloe vera* reduced water loss levels. According to Martinez-Romero et al. (2006) research, *Aloe vera* pulp films retarded water loss and controlled gas exchange, thereby reducing respiration and oxidation reactions, during the storage period. The reduction in weight loss was probably due to the effects of these coatings as a semi-permeable barrier against oxygen, carbon dioxide, moisture, and solute movement, thereby reducing respiration, water loss and oxidation reaction rates (Baldwin et al., 1999).

Titratable acidity

Apple fruits with coating presented a statically higher titratable acidity (malic acid) during storage in spite of the slight decrease observed (Table 3). At the first sampling, the degree of acidity in Golden Delicious cultivar was higher (0.38 %) compared to the Red Delicious cultivar (0.25%). As shown in Table 3, in uncoated fruits (control treatment), TA decreased significantly during storage, whereas the degrees of titratable acidity in coated fruits were considerably maintained (especially coating at a concentration of 10 kg m^{-3}). These results agreed with those found by Emamifar and Bavaisi (2017), that demonstrated strawberries coated with tragacanth and *Aloe vera* gum prevented reduction of TA during storage time and the variation of TA values in uncoated fruits during storage were significantly higher than those of coated fruits. Reduction in TA for uncoated fruits is due to conversion of acids into sugars and their further utilization in the metabolic processes of the fruit or probably due to the use of organic acids (such as citric acid) in the respiration process. The acidity of the fruit is an important character to determine its quality and acceptability (Gol et al., 2013; Sophia et al., 2015). TA in apples treated with corn oil was higher compared to the control (Ju & Curry, 2005) and results of the present research conformed to those found by them. It was reported that use of almond oil as a coating in oranges (cv. Valencia) preserved fruit moisture and titratable acidity and also the stability of soluble solid materials (Makki & Panahi, 2013).

Table 4. Effect of different tragacanth gum concentration on pH of coated and uncoated apple cultivars during storage time

Treatments (kg m^{-3})	Cultivar	Time (month) 0	1	2	3	4
0	Red Delicious	3.4^{fh}†	3.53^{e}	3.67^{d}	4.1^{c}	4.3^{a}
	Golden Delicious	2.97^{rs}	3.27^{il}	3.53^{e}	3.77^{d}	4.23^{ab}
5	Red Delicious	3.367^{fi}	3.33^{gj}	3.33^{gj}	3.33^{gj}	3.43^{eg}
	Golden Delicious	3^{qs}	3.03^{pr}	3.1^{nq}	3.23^{jm}	3.67^{d}
10	Red Delicious	3.27^{il}	3.3^{hk}	3.17^{lo}	3.067^{or}	3.13^{mp}
	Golden Delicious	2.97^{rs}	3.07^{or}	3.07^{or}	3.167^{lo}	3.3^{hk}
15	Red Delicious	3.27^{il}	3.47^{ef}	3.3^{hk}	3.33^{gj}	3.4^{fh}
	Golden Delicious	2.9^{s}	3.2^{kn}	3.47^{ef}	3.67^{d}	4.13^{bc}

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

Table 5. Effect of different tragacanth gum concentration on SSC of apple cultivars during storage time

Cultivar	Treatments (kg m^{-3})			
	0	5	10	15
Red Delicious	11.93^{bc}†	12.67^{ab}	12.8^{a}	12.33^{ac}
Golden Delicious	12.73^{ab}	12.13^{ac}	11.6^{c}	11.67^{c}

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

Table 6. Effect of storage time on SSC of apple fruit

Attribute	Time (month)				
	0	1	2	3	4
SSC	11.58^{b}†	11.96^{b}	11.71^{b}	12.71^{a}	13.2^{a}

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

Fruit juice pH

At the beginning of the storage period, the pH value of fruit juice in the Golden Delicious cultivar was lower compared to the Red Delicious cultivar and in general, significant differences were observed between coated and uncoated fruits. However, the tragacanth gum was more effective in preserving the pH of Red Delicious cultivar and tragacanth gum at 10 kg m^{-3} concentration had the best result (Table 4). Coating maintained pH values of blueberries at lower levels compared to the uncoated fruit samples (Vieria et al., 2016). Benitez et al. (2013) showed that kiwifruit coated with *Aloe vera* slightly lower the initial pH.

Soluble solids content

In comparison with the control treatment, the tragacanth treated fruits had higher SSC in Red Delicious cultivar but this coating reduced them in the Golden Delicious cultivar (Table 5). During the storage time, SSC of fruit juice was significantly increased in both cultivars (Table 6). Increases in soluble solids content during storage can be related to fruit weight loss, which in turn increases concentrations of soluble solid materials (Tanda-palmu & Grosso, 2005).

Aloe vera gum coating significantly affected the contents of soluble solids content in Granny Smith apples and Starking Hardy Giant cherries. So that increases in concentrations of *Aloe vera* gel prevented increases in the contents of soluble solids during storage (Ergun & Satici, 2012; Martinez-Romero et al., 2006). Furthermore, Benitez et al. (2013) stated that edible *Aloe vera* gum coating on kiwifruit (cv. Hayward) stored for 3-5 days under passive modified atmosphere packaging at 4 ºC preserved soluble solids content. Hassanpour (2015) showed that *Aloe vera* gel treated raspberries had higher SSC levels and the difference was significant. Depletion of SSC in the fruit could be explained by a high metabolism of fruits and senescence processes.

The increase in SSC of strawberry fruits during storage could be related to the degradation of cell-wall polymers or other polysaccharides such as hemicelluloses and water loss (Hernandez-Munoz et al., 2008; Tanada-Palmu & Grosso, 2005). The lowest SSC were recorded in strawberries treated with 50% *Aloe vera* gum and 50% tragacanth gum, compared to other treatments and control samples (Emamifar & Bavaisi, 2017).

Isolation and culture of Penicillium

Only tragacanth gum at 15 kg m^{-3} concentration inhibited significantly the growth of fungus as compared to the control (PDA culture free of tragacanth) and other gum treatments (Fig. 1). It has been reported that the tragacanth extract has antimicrobial properties (Ghayempour et al., 2015). Studies suggest that the geraniol in tragacanth possesses antibacterial and antifungal properties. Furthermore, it has been reported that the carvacrol in tragacanth extract exhibits a broad spectrum of antimicrobial effects (Gil et al., 2000).

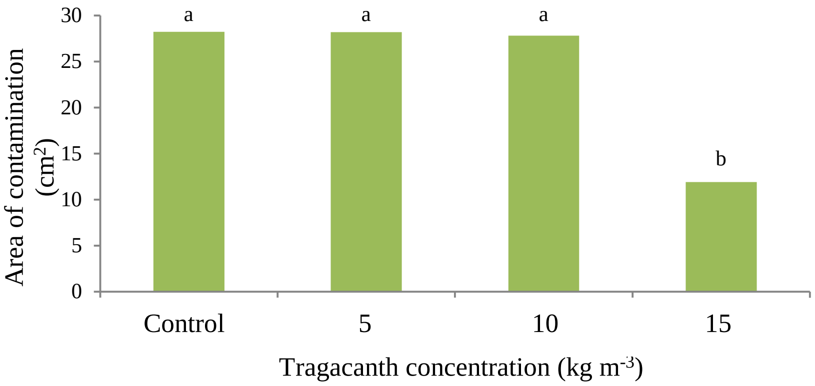

Fig. 1. Effect of tragacanth gum concentration on the growth of fungus in PDA

CONCLUSION

Nowadays gums are used extensively in various fields of the food industry. Findings of this study demonstrate the potential of using tragacanth gum as a coating for improved postharvest shelf life and maintaining the quality of apple fruits hence reduce postharvest losses. The results showed that in both cultivars (Red Delicious and Golden Delicious) 10 kg m^{-3} tragacanth concentration significantly increased shelf life evidenced by a reduced decrease in firmness and considerably reduced fruit weight loss, during the 120 days of storage. The study provides minimizing post-harvest losses by using an appropriate edible coating. Since tragacanth as an edible plant does not pose any environmental hazard and is easily available in Iran. Further investigation is needed to elucidate the underlying relationship between tragacanth treatment and other attributes such as antioxidant enzymes and capacity in apple fruits.

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پوشش خوراکی جدید برای میوه‌ی سیب

بهنام جهانشاهی، اعظم جعفری، محمدرضا وظیفه شناس و جلال غلام نژاد

چکیده

پوشش‌های خوراکی براساس تکنولوژی دوستدار محیط زیست هستند که در بسیاری از محصولات، انتقال رطوبت، مواد محلول و معطر، تبادل گازی و مسیرهای اکسایشی را کنترل می‌کنند. هدف از این پژوهش بررسی تاثیر ژل کتیرا در غلظت های ۰، ۵، ۱۰ و ۱۵ $kg\ m^{-3}$ بر عمر انباری و کیفیت خوراکی سیب رقم‌های رد دلیشز و گلدن دلیشز است. بعد از اعمال تیمارها، میوها در یک سردخانه در دمای$^{\circ}C$ ۱±۰ و رطوبت نسبی ۸۵ تا ۹۵ درصد نگهداری شدند. کاهش وزن، کیفیت ظاهری، میزان آلودگی و مقبولیت کلی آنها بعد از ۰، ۳۰، ٦۰، ۹۰ و ۱۲۰ روز نگهداری در سردخانه اندازه‌گیری و با میوه‌های سیب بدون پوشش مقایسه شد. براین اساس ژل کتیرا بطور معنی‌داری هدررفت آب را در مقایسه با شاهد کاهش داد و کاهش وزن در میوه‌های بدون پوشش هشت برابر میوه‌های تیمار شده با غلظت ۱۰ $kg\ m^{-3}$ ژل کتیرا بود. این پوشش باعث حفظ سفتی بافت میوه در سردخانه می‌شود و از آردی شدن سیب‌ها جلوگیری می‌کند. پوشش ژل کتیرا بطور مطلوبی کیفیت خارجی را حفظ کرده و میزان آلودگی، مشخصه‌های حسی و ظاهری میوه‌ها را بهبود بخشیده، باعث حفظ فاکتورهای کیفی سیب شده و از رسیدن میوه در حین انبارداری جلوگیری می‌کند. در بین تیمارهای مختلف، پوشش ۱۰ $kg\ m^{-3}$ از سایر تیمارها موثرتر بود و اسیدیته و pH آب‌میوه را در سطح مطلوبی حفظ کرده و از افزایش محتوای مواد جامد محلول طی انبارداری جلوگیری کرد.

کلمات کلیدی: *Astragalus*، گلدن دلیشز، رد دلیشز، عمر انباری، ژل کتیرا