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# Effect of mixed edible coatings containing gum tragacanth and Aloe vera on postharvest quality of strawberries during storage

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## Abstract

The effects of mixed coating based on aloe vera (AG) and gum tragacanth (GT) on the microbial, physicochemical and sensorial properties of fresh strawberries were evaluated during 20 days of storage (1 °C, 95 % RH) compared to uncoated fruits. The coating solutions were prepared by mixing solution of AG diluted 1:3 with distilled water and GT solution (0.6 % w/v in distilled water) at different concentrations (25 % AG +75 % GT, 50 % AG +50 % GT and 75 % AG +25 % GT). Microbial stability (fungi (yeasts and molds) and total aerobic bacteria), physiochemical characteristics (ascorbic acid (AA), weight loss, firmness, titratable acidity, soluble solid content (SSC), anthocyanin content, total phenolic and antioxidant activity) and sensory attributes (color, taste, odor and overall) of the samples were evaluated after 0, 4, 8, 12, 16 and 20 days of storage compared to uncoated fruits. Comparing with untreated fruits, 50 % AG +50 % GT treatment significantly ($p<0.05$) decreased the microbial growth, weight loss and AA degradation and maintained firmness, anthocyanin and phenol contents and antioxidant activity. A greater visual acceptance was observed in fruits treated with 50 % AG + 50 % GT. The combination of AG/GT solution as a proper coating formulation in addition to have high antimicrobial activity; have great potential to extend shelf life of fresh strawberries.

**Keywords:** Strawberry; Aloe vera; Gum tragacanth; Shelf life.

## Introduction

Strawberry fruits have a short shelf life, so after harvest, the marketability of them will reach about 5 d at temperature between 0 and 4 °C with 90-95 % relative humidity (Jiang *et al*. 2001). The loss of fresh strawberries can reach 40 % from harvesting to consumption (Park *et al*. 2005). There have been many studies on reducing postharvest losses of strawberry fruits using pre or post-harvest treatments including: polyamines (Ponappa *et al*. 1993), methyl jasmonate (Ayala-Zavala *et al*. 2005), UV (Erkan *et al*. 2008), nitric oxide (Wills *et al*. 2000), 1-methylcyclopropene (Bower *et al*. 2003) ultrasound (Aday *et al*. 2013), salicylic acid (Zhang *et al*. 2010) as well as application of edible coating (Tanada-Palmu and Grosso 2005; Del-Vallea *et al*. 2005). Application of edible coating on perishable fruits such as strawberries or fresh cut fruits is one of the most common methods to increase their shelf life through reducing the respiration rate, water loss, improving the sensory attributes and retarding the microbial growth (Bifani *et al*. 2007). Alginate, cellulose, chitosan, chitin, lipids, mucilage, milk protein, starch, wax, and zein have been widely used as an edible coating in the food industry (Valverde *et al*. 2005). Gum tragacanth is one of the most popular herbal gum that exudates from stem of *Astragalus gummifer*. Safety assessment and approving their use in foods (emulsifying agent, stabilizer, filing and thickening agent) have been confirmed (E-number E413) by the Scientific Committee for Food of the European Community (Gavlighi *et al*. 2013; Samanta *et al*. 2010; Fayazzadeh *et al*. 2014). Gum tragacanth is an acidic hetero-polysaccharide that contained some protein-bounded polysaccharides (Saffari *et al*. 2013). It consists of two different fractions including tragacanthin (water-soluble) and bassorin (water insoluble) with different rheological

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properties (Balaghi *et al*. 2010). Aloe vera (*Aloe barbadensis Miller*) is a natural plant with functional properties such as antibacterial, antifungal and antioxidant activity (Nejatzadeh-Barandozi 2013). The transparent gel of aloe vera that contains nutritional components has also edible and medicinal values (Zafari *et al*. 2015). Two main components obtained from the fresh harvested aloe vera leaves including liquid fraction containing bitter excaudate and semisolid fraction containing parenchyma tissue. Moreover, it has improved postharvest life quality of fruits such as grape, nectarine, papaya and pomegranate arils (Valverde *et al*. 2005; Navarro *et al*. 2011). Many researches have been done on the applications of gum tragacanth in food formulations. Recently, it has been used in food packaging (Mostafavi *et al*. 2016). There are few reports on the use of tragacanth as an edible coating. The main mechanism of the film formation in polysaccharide films is the breaking apart polymer segments and reforming of the polymer chain into film matrix or gel that achieved by several film-forming mechanisms including solvent evaporation, creating hydrophilic and hydrogen binding or electrolytic and ionic crosslinking (Park *et al.* 2014). The safety of biopolymer materials, solutions and additive that used as fruit coatings is very important for its application on the food industry (Šuput *et al.* 2015). The main purpose of this research is to evaluate the effects of gum tragacanth combined with aloe vera gel on the microbial contamination, physicochemical and sensory properties of fresh strawberries during cold storage.

## Materials and Methods

In the first step, the optimal concentration of diluted gum tragacanth in distilled water as an edible coating solution for fresh strawberries was determined and in the next step, the effects of the mixed edible coating containing aloe vera (AG) and gum tragacanth (GT) at different GT/ AG ratio on the postharvest quality of strawberries were evaluated.

### Plant material

Under the guidance of expert botanists, at the University of Kurdistan, fresh strawberries (Fragaria X anannasa Duch.), cv. 'Parous', were harvested at maturity stage (based on 80 % red color on the surface) from a commercial farm in Sanandaj, Iran. They were immediately precooled (at 1$^{o}$C for 1 hour) after harvest and were directly transported to the laboratory. Then, fresh fruits were sorted for uniform size, color, and removed unripe and damaged and then were stored at 1 $^{o}$C and 95 % RH.

### Preparation of coating formulation (Gum tragacanth solution)

The ribbon tragacanth gum (slight-yellowish clear appearance) was purchased from the local market in Sanandaj, Iran. They were grinded (National, K039131, Cixi City, China) and sieved (Retch sieve, 0.425 mm, Lincoln, U.K.) to produce fine powder. The powdered gum tragacanth at different concentrations (0, 0.3, 0.6 and 0.9% w/v; of total solid) was added gently to the distilled water, mixed for 1 h and let stand overnight at ambient temperature to fully hydrate. Gum tragacanth solutions were pasteurized in a water bath at 70°C for 45 min and were cooled to 25$^{o}$C (Marpudi *et al*. 2011).

### Coating and storage

Strawberry fruits were immersed and the coating treatments were performed at 25°C by immersing the strawberries for 5 min in gum tragacanth coating solutions and dried on a sterile stainless-steel screen under fans for about 1 h. Gum tragacanth solutions were pasteurized in a water bath at 70°C for 45 min and were cooled to 25$^{o}$C (Marpudi *et al.* 2011). Sterile distilled water was used as the control solution. The coated and uncoated (Control) fruits were then packaged in polyethylene packages (72 packages, each containing 15 pieces of strawberries) and stored at 1°C with 95 % RH. The samples were evaluated at three replications (Each replicate consisted of one packed with 15 plants) for their microbiological, physicochemical, and sensory characteristics

at 0, 4, 8, 12, 16 and 20 d of storage. After the selection of the best concentration of gum tragacanth solution, it was applied for preparing the mixed coating solution with aloe vera gel solution.

**Preparation of coating formulation (Aloe vera gel)**

Aloe vera leaves were cut from greenhouse-grown plants (University of Kurdistan, Sanadaj, Iran). They were washed with water, disinfected (in a 2% sodium hypochlorite solution for 30 min) and rinsed with distilled water. Aloe vera gel matrix was then separated from the outer cortex of leave, ground, and filtered to produce a fresh aloe vera gel. After pasteurization (at 70ºC for 45 min) the gel was cooled to 25ºC (Marpudi *et al*. 2011). The coating solution was prepared by aloe vera gel diluted 1:3 with sterile distilled water (Valverde *et al*. 2005; Hassanpour 2015).

**Preparation of coating formulation (Aloe vera and Gum tragacanth solutions)**

Mixtures of pasteurized (GT) and aloe vera (AG) solutions at different concentrations (25% AG+ 75 % GT, 50% AG+ 50% GT and 75% AG+ 25% GT) were prepared as an edible coating. Fruits were dipped in coating solutions or sterile distilled water as the control solution, at 25°C for 5 min. They dried on a sterile stainless-steel screen under fans for about 1 h to ensure surface dryness. The coated and uncoated (control) fruits were packaged (72 packages, each containing 15 pieces of strawberries) and stored (under the same conditions as mentioned above). Samples were evaluated exactly according to section 2.3. (Coating and storage).

**Microbiological evaluations**

At each sampling time, for each replicate a mixed sample with quarter of each fruit was transferred aseptically to a stomacher bag and homogenized. Decimal dilutions of the suspension of strawberries in sterile peptone water (0.1%) were prepared. With the spread plate and pour plate methods, enumeration of total aerobic bacteria (at 30°C for 2 d), yeasts and molds (at 25°C for 2d) were carried out on the plate count agar (PCA, Scharlau Chemie, S.A., Barcelona, Spain) and the potato dextrose agar (PDA, Scharlau Chemie, SA., Barcelona, Spain), respectively. Serial dilutions ($10^{-2}$ to $10^{-3}$) were performed in triplicate and dilutions were plated in duplicate. The results were expressed as colony-forming units (CFU) per gram (Sogvar *et al*. 2016).

**Physicochemical properties**

Weight loss (WL) and Firmness

The weight of each packaged (replicate) was recorded immediately after packaging and after each 4d of storage. Weight loss was expressed as the percentage loss of the initial fresh weight. The firmness of strawberries in each box replicate was evaluated by texture analyzer (Santam, STM-1) with an 8 mm probe with constant speed of 20 mm $min^{-1}$. Two different measurements were done on opposite sides of the central zone of each fruit (Sogvar *et al.*, 2016). Force values were expressed as newton (N).

Titratable acidity (TA), soluble solid content (SSC) and Ascorbic acid

A mixed sample of all fruit with one-eighth segments of each fruit per replicate juiced together and used for measuring the titratable acidity (TA), soluble solid content (SSC) and ascorbic acid. TA was measured based on titrimetric method by using 0.1 M NaOH (to pH 8.1) and was expressed as percentage of citric acid per 100 mL fruit juice (AOAC, 2002). SSC was detected by digital refractometer (AOAC, 2002). Ascorbic acid was determined based on titrimetric method by 2,6-dichlorophenolindophenol as a titrant (AOAC 967.21) and expressed as mg $kg^{-1}$ fresh weight basis of fruits (AOAC, 2002).

Total anthocyanin content (TAC), total phenolic concentrations (TPC) and Total antioxidant activity (TAA)

At the sampling time, a bulked sample of all fruits with 1/8 th of each fruit per replicate was cut, frozen and stored at -80ºC and they were used for determination of total anthocyanin content (TAC), total phenolic

(TP) concentrations and total antioxidant activity. Total anthocyanin content was measured by a pH differential method (Cheng and Breen 1991). The absorbance of the combined sample extract with quarter of each fruit was read at 510 nm and 700 nm in buffers at pH 1.0 and 4.5. Results were expressed as milligrams of pelargonidin 3-glucoside (P 3-G) equivalents per kilogram of fresh weight. Total phenolic concentrations were determined according to Folin Ciocalteu method using gallic acid as the standard curve and the results were presented as milligram of gallic acid equivalent per kilogram of fruit fresh weight (Singleton *et al.*, 1999). Measurement of the total antioxidant activity of frozen samples was carried out by 2, 2-diphenyl-1-picryl-hidrazil (DPPH) radical-scavenging method (Sanchez Moreno *et al*. 1999). The absorbance was measured at 517 nm, using a spectrophotometer (UNICO UV-2100, Shanghai, China) and the results presented as the percentage inhibition of DPPH radicals.

**Sensory analysis**

Sensory characteristics (color, odor, taste, and overall) of uncoated and coated strawberries were evaluated based on a 5-point scale (extremely like= 5, moderately like= 4, neither liked nor disliked= 3, moderately dislike= 2 and extremely dislike= 1) by 10 expert panelists. Fruits were sampled at 0, 4, 8, 12, 16 and 20 days of storage (Emamifar *et al.* 2010).

**Statistical analysis**

Analysis of variance was carried out using the SAS statistical software release 6.12 (SAS Institute, Cray, NC) based on completely randomized designs. Significant differences among the data were represented as $p< 0.05$.

**Results and Discussion**

**Experimental section 1**

Table 1, shows the variations of the mean microbial populations, weight loss and ascorbic acid content in the tragacanth coated fruits compared to control (uncoated) during storage (at 1$^{o}$C and 95% RH). In all samples, the microbial populations and weight loss increase and ascorbic acid content decreases at different rates as the storage time increases, significantly ($p<0.05$). The mean initial populations of yeasts and molds and total aerobic bacteria in freshly harvested strawberries immediately after packaging (control samples) were found to be 1.47 log CFU $g^{-1}$and 1.38 log CFU$g^{-1}$, respectively. For the coated strawberry fruits with 0.6% gum tragacanth solution, significance decreases were observed in yeasts and molds and total aerobic bacteria populations compared to all other coated and uncoated samples, after 20 d. The weight loss of uncoated fruits was increased significantly ($p<0.05$) up to 34.15% as compared to 26.58, 18.85 and 22.38 % for strawberries coated with 0.3, 0.6 and 0.9% gum tragacanth solutions, respectively. Ascorbic acid degradation in control samples was higher than in other coated samples after 20 d of storage. At the end of storage period, strawberries coated with 0.6% gum tragacanthe solution maintained higher ascorbic acid content (64%) compared to other that coated with 0.3% gum tragacanthe solution (52%), 0.9% gum tragacanthe solution (58%) and control (46%), significantly ($p<0.05$). However, the 0.6% w/v solution of gum tragacanth treatment shows a significant ($p<0.05$) effect on reducing the microbial populations and weight loss and maintaining the ascorbic acid content in strawberry fruits as compared to the other treatments and control during storage. These results are in agreement with the findings of Mohebbi *et al*. (2012). Treviño-Garza *et al*. (2015) found that edible active coatings based on polysaccharides reduced the microbial growth in coated strawberry fruits and increased their shelf life up to 15 d. Gol *et al*. (2013) showed that the combination of Hydroxypropyl methyl cellulose (HPMC) and chitosan as an edible coating can maintain the ascorbic acid content in fresh strawberries during cold storage. Significant reductions of weight loss were observed in strawberries coated with cassava starch (Garcia *et al*. 2012) and chitosan-based edible coatings (Han *et al*.

2004) during cold storage. Strawberry fruits coated with 0.6% w/v gum tragacanth solution showed significantly ($p<0.05$) higher values of firmness, total anthocyanin, total phenol, antioxidant activity and sensory attributes and lower values of SSC and TA compared to other treatments and control (data not shown).

**Table 1. Effect of tragacanth (mean ± sd) [a] on the yeasts and molds, total aerobic bacteria populations, weight loss and ascorbic acid of strawberries stored at 1 °c for 20 d.**

| | Tragacanth concentration (%) | Storage time(days) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 4 | 8 | 12 | 16 | 20 |
| Molds and Yeasts (log CFU $g^{-1}$) | 0 | 1.47 $^{k}$ ± 0.05 | 2.25 $^{g}$ ± 0.04 | 2.61 $^{e}$ ± 0.01 | 2.81$^{cd}$ ± 0.04 | 3.04 $^{b}$ ± 0.02 | 3.37 $^{a}$ ± 0.05 |
| | 0.3 | 1.47 $^{k}$ ± 0.04 | 1.88 $^{j}$ ± 0.03 | 2.29 $^{g}$ ± 0.05 | 2.57 $^{e}$ ± 0.05 | 2.78 $^{d}$ ± 0.02 | 2.89 $^{c}$ ± 0.07 |
| | 0.6 | 1.47 $^{k}$ ± 0.04 | 1.61 $^{j}$ ± 0.03 | 1.93 $^{i}$ ± 0.02 | 2.08 $^{h}$ ± 0.05 | 2.39 $^{f}$ ± 0.05 | 2.57 $^{e}$ ± 0.02 |
| | 0.9 | 1.47 $^{k}$ ± 0.01 | 1.62 $^{j}$ ± 0.07 | 2.06 $^{h}$ ± 0.01 | 2.39 $^{f}$ ± 0.05 | 2.61 $^{e}$ ± 0.07 | 2.74 $^{d}$ ± 0.02 |
| Total aerobic bacteria (log CFU $g^{-1}$) | 0 | 1.38 $^{m}$ ± 0.03 | 2.13 $^{gh}$ ± 0.01 | 2.45 $^{d}$ ± 0.04 | 2.70 $^{c}$ ± 0.01 | 2.91 $^{b}$ ± 0.03 | 3.29 $^{a}$ ± 0.05 |
| | 0.3 | 1.38 $^{m}$ ± 0.07 | 1.84 $^{ij}$ ± 0.03 | 2.04 $^{h}$ ± 0.03 | 2.26$^{ef}$ ± 0.06 | 2.54 $^{d}$ ± 0.01 | 2.78 $^{c}$ ± 0.08 |
| | 0.6 | 1.38 $^{m}$ ± 0.06 | 1.54 $^{l}$ ± 0.04 | 1.76 $^{j}$ ± 0.02 | 1.91$^{l}$ ± 0.05 | 2.19 $^{fg}$ ± 0.08 | 2.48 $^{d}$ ± 0.07 |
| | 0.9 | 1.38 $^{m}$ ± 0.02 | 1.65 $^{k}$ ± 0.06 | 1.91 $^{l}$ ± 0.01 | 2.16 $^{g}$ ± 0.04 | 2.34 $^{e}$ ± 0.02 | 2.70 $^{c}$ ± 0.02 |
| Weight loss (%) | 0 | 0.00 $^{j}$ ± 0.00 | 6.75 $^{i}$ ± 0.70 | 15.76 $^{e}$ ± 0.36 | 21.10 $^{c}$ ± 0.40 | 26.64 $^{b}$ ± 0.45 | 34.15 $^{a}$ ± 1.01 |
| | 0.3 | 0.00 $^{j}$ ± 0.00 | 6.10 $^{i}$ ± 0.28 | 12.90 $^{f}$ ± 0.65 | 18.09 $^{d}$ ± 0.60 | 21.57 $^{c}$ ± 0.22 | 26.58 $^{b}$ ± 0.17 |
| | 0.6 | 0.00 $^{j}$ ± 0.00 | 5.20 $^{i}$ ± 0.69 | 9.12 $^{h}$ ± 0.44 | 12.51 $^{fg}$ ± 0.48 | 15.69 $^{e}$ ± 0.18 | 18.85 $^{d}$ ± 0.19 |
| | 0.9 | 0.00 $^{j}$ ± 0.00 | 5.95 $^{i}$ ± 0.09 | 10.85 $^{gh}$ ±0.13 | 15.04 $^{e}$ ± 0.34 | 17.78 $^{d}$ ± 0.24 | 22.38 $^{c}$ ± 0.22 |
| Ascorbic acid (mg kg-1 ) | 0 | 555.50 a ± 3.34 | 435.50 e ± 11.1 | 382.25 fg ± 7.79 | 347.75 ji ± 1.12 | 307.75 l ± 3.36 | 255.50 m± 11.12 |
| | 0.3 | 555.50 a ± 5.57 | 487.70 c ± 8.86 | 425.50 e ± 2.22 | 371.15 gh± 1.16 | 335.50 jk ± 1.19 | 294.40 l ± 3.39 |
| | 0.6 | 555.50 a ± 1.12 | 532.25 b ± 2.23 | 488.87 c ± 3.34 | 422.25 e ± 7.72 | 385.50 fg ± 8.88 | 355.50 hi ± 1.16 |
| | 0.9 | 555.50 a ± 7.78 | 592.20 b ± 1.14 | 455.50 d ± 3.32 | 395.50 f ± 6.63 | 355.51 hi ± 3.34 | 326.65 k ± 1.09 |

Values followed by the same letter in the same row are not significantly different ($p < 0.05$).

**Experimental section 2**

**Microbiological evaluation**

Strawberry fruits can become contaminated with spoilage microorganisms during growth in the field, harvesting and postharvest handling, or during storage (Barth *et al.* 2009). Moreover, the fruit surface has long been considered a suitable environment for the growth of microorganisms. More generally, fruits surface microbes have impact on the rates of food spoilage (Akhtar *et al.* 2016).Freshly harvested strawberries contain more nutrients and high water content. Therefore, they are highly susceptible to microbial decay. There are multiple factors that considerably affect microbial decay during storage including temperature, relative humidity and $O_2$ concentration (Kader 1998). Edible coating act as barriers to moisture and oxygen during storage and delayed decay development in coated fruits as compared to uncoated (Valverde *et al.* 2005). The variations of the mean microbial populations in coated fruits compared to control (uncoated) during cold storage are shown in Fig. 1. For all samples, the microbial population increased significantly ($p<0.05$) at different rates as the storage time increased. The populations of yeasts and molds and total aerobic bacteria in control samples reached 3.81 log $CFUg^{-1}$and 3.82 log $CFUg^{-1}$, respectively, after 20 d. According to Fig. 1. The mixed gum based treatments have significant ($p<0.05$) effects on retarding microbial growth in all strawberry samples during cold storage. In comparing all treated and untreated samples, 50 % GT + 50 % AG treatment showed the most antifungal (2.72 log CFU $g^{-1}$) and antibacterial (2.78 log CFU $g^{-1}$) activity on fresh strawberries during 20 d of storage at 1 $^{o}$C. The effect of the volume ratio of AG to GT on antimicrobial activity of mixed coating material is

pronounced significantly ($p<0.05$). As shown in Fig. 1, increased AG: GT ratio is believed to be related to the decreased antimicrobial activity of coating materials. However, coating formulation containing lower concentrations of aloe vera (50%) have significantly more antimicrobial activity than coating formulation containing 75% of aloe vera ($p<0.05$). Aloe vera contains several special compounds with antimicrobial activity, including anthraquinones (Garcia-Sosa *et al*. 2006), dihydroxy- anthraquinones (Wu *et al*. 2006) and saponins (Reynolds and Dweck 1999). Ferro *et al*. (2003) showed that aloe vera gel exhibited an antimicrobial activity against gram positive and gram-negative bacteria as well as yeasts and molds. Moreover, the antifungal activity of the aloe vera gel against fungi spores such as *Penicillium*, *Botrytis* and *Alternaria* and against mycelium growth of fungi such as *Rhizoctonia*, *Fusarium and Colleotrichum* (Saks and Barkai-Golan 1995; Jasso de Rodriguez *et al*. 2005) have reported. Shelf life extension and microbial load reduction of pomegranate arils, table grape and sweet cherry using aloe vera gel as an antimicrobial coating have been reported (Martínez-Romero *et al*. 2013; Valverde *et al*. 2005; Martinez-Romero *et al*. 2006). Recently, antimicrobial activity of gum tragacanth against some gram negative and gram-positive bacteria and molds and yeasts has been reported (Ghayempour *et al*. 2015; Singh *et al*. 2015). Muthulakshmi (2013) showed that the interaction between gum tragacanth amino groups with gram-negative bacterial cell wall as well as the binding of gum tragacanth carboxylate groups with the gram-positive bacterial cell and the fungal cell wall are the most important reasons for antimicrobial activity of this gum. Moreover, the complex structure and high molecular weight of gum tragacanth have more positive effects on antimicrobial activity of gum tragacanth (Muthulakshmi 2013).

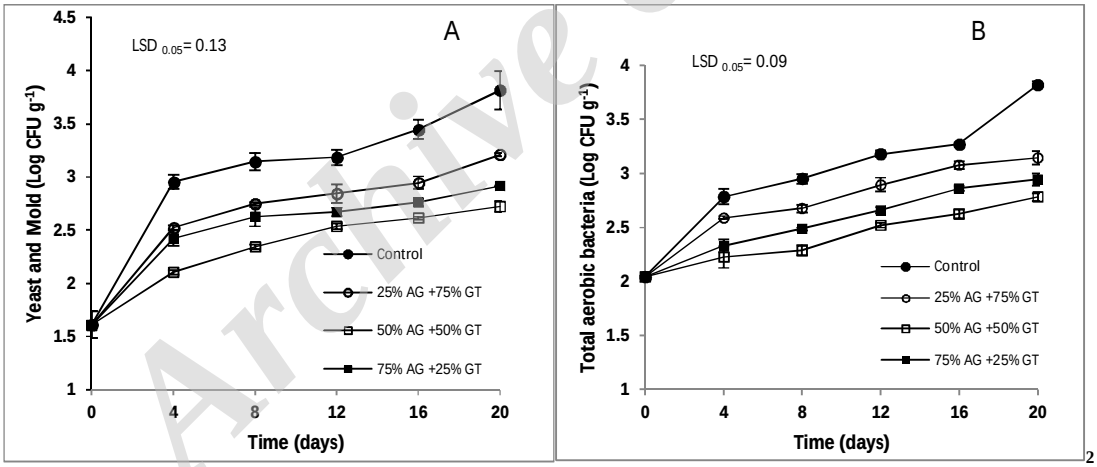


**Fig. 1. Effect of mixed coating based on aloe vera (AG) and gum tragacanth (GT) on the yeasts and molds populations (a) and total aerobic bacteria populations (b) of strawberries stored at 1 °C for 20 d. Vertical bars represent standard error (n = 3).**

**Weight loss**

According to Fig. 2.A., in all samples, the weight loss increases at different rates as the storage time increases, significantly ($p<0.05$). Strawberries coated with 50% GT+ 50% AG showed the lower rate of weight loss compared to the others, so that after 20 d of storage, the weight loss of uncoated fruits reached to 26.6% as compared to 21.1% (25% AG+ 75% GT), 18.7 %(50% AG+ 50% GT) and 19.3% (75% AG+ 25% GT), respectively (Fig. 2.A.). No significant differences were observed in weight loss between two-treatment coating including 50% AG+ 50% GT and 75% AG+ 25% GT, except on the 8$^{th}$ d ($p<0.05$). Weight loss often occurred due to water evaporation in

fruits and vegetables during respiration process (Yaman and Bayoindirli 2002). However, the main impact of coatings application are based on their hygroscopic properties, which form a water barrier layer between fruits and environments and reduce the fruit surface evaporation (Mohebbi *et al*. 2012). Aloe vera coating has also been reported to reduce the weight loss of table grapes, sweet cheery, apple and papaya stored at cold storage (Valverde *et al*. 2005; Martinez-Romero *et al*. 2006; Marpudi *et al*. 2011; Ergun and Satici 2012). Mohebbi *et al*. (2012) reported that the combination of aloe vera and gum tragacanth are more effective on reducing the weight loss of button mushroom. It can be concluded that the combination of aloe vera and gum tragacanth in the specified concentration ranges have a synergetic effects on reducing the weight loss of the strawberries during cold storage.

**Firmness**

The firmness is one of the most important physical quality characteristics of fruit during storage (Pasquariello *et al*. 2013). As shown in Fig. 2.B., with increasing the storage time the rate of softening increased in all of strawberries, but it was faster in uncoated than those of coated samples (Fig. 2.B.). After 20 d, firmness value decreased from 3.05 N to 1.41, 1.73, 2.26 and 1.93 N in uncoated and coating treatments including 25% AG+ 75% GT, 50% AG+ 50% GT and 75% AG+ 25% GT, respectively (Fig. 2.B.). 50% AG+ 50% GT coating was more effective in firmness retention of the strawberries compared to others ($p<0.05$). These results are in agreement with the results reported by many studies which stated that the firmness of strawberry fruits treated with edible coating including cactus mucilage (Del-Valle *et al*. 2005), starch (García *et al*. 2012) and gluten (Tanada-Palmu and Grosso 2005) were maintained during storage. Degradation of the middle lamella of the cortical parenchyma cells and cell separation and subsequent microbial infection are the main reasons for the softening of strawberry fruits during storage (Rahman *et al*. 2016).

**Titrable acidity (TA) and soluble solids content (SSC)**

For all samples, SSC increased and TA decreased during storage (Fig. 2.C and D). The variations of TA and SSC values in uncoated fruits during storage were significantly ($p<0.05$) higher than those of coated fruits. According to Fig. 2C. and D, after 20 d of storage; the highest TA (0.705%) and the lowest SSC (6.9%) were recorded in strawberries treated with 50% AG+ 50% GT, compared to the other treatments and control samples, indicating uncoated strawberries presented a more pronounced ripening development than coated strawberries, similarly to that found in starch-coated strawberry (Mali and Grossmann, 2003). These results agreed with those found by EL Gaouth *et al*. (1991), Pelayo *et al*. (2002) and Koyuncu (2004). Zheng *et al*. (2007) showed that decreasing in titratable acidity of strawberry fruits during cold storage caused by increasing their respiration rate. The increase in SSC of strawberry fruits during storage could be related to degradation of cell-wall polymers or other polysaccharides such as hemicelluloses and water loss (Hernandez-Munoz *et al*. 2008; Tanada-Palmu and Grosso 2005).

**Ascorbic acid content**

Ascorbic acid content of strawberries can be influenced by pre-harvest and postharvest factors including cultivar, growing season, environmental conditions, harvest time and storage conditions (Skrovankova *et al*. 2015; Cordenunsi *et al*. 2005). The average ascorbic acid content of strawberry fruits is ranged from 190 mg $kg^{-1}$ to 715 mg $kg^{-1}$ (Lee and Kader 2000). According to Fig. 3.A., ascorbic acid in all coated and uncoated samples reduced over 20 d of storage. Coating containing 50% AG+ 50% GT was the most effective treatment to maintain ascorbic acid (29.26%) in strawberries during storage up to 20 d while this value was decreased to 17.29 % for uncoated and 23.31 and 28.35% for coating containing 75% AG+ 25% GT and

25% AG+ 75% GT, respectively. Autoxidation is one of the main reasons for ascorbic acid depletion during storage of fruits (Plaza *et al*. 2006). Coating materials provide a protective thin layer between the fresh fruit and its surrounding atmosphere that decrease the moisture transfer, $O_2$, and $CO_2$ exchange (Tapia *et al*. 2008; Atress *et al*. 2010). Adetunji *et al*. (2012) have found that pineapple coated with aloe vera gel showed the shelf life extension by decreasing the oxygen permeability.

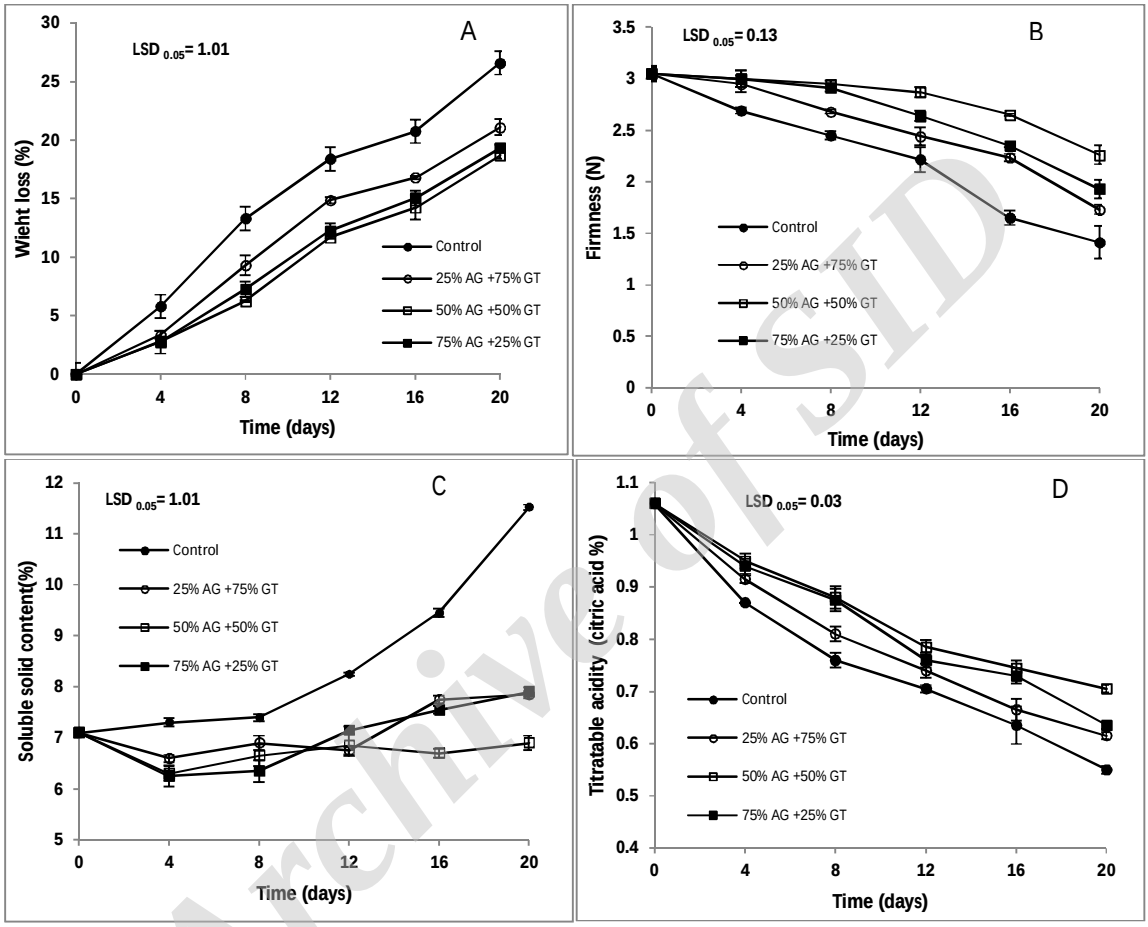


**Fig. 2. Effect of mixed coating based on aloe vera (AG) and gum tragacanth (GT) on the weight loss (A), Firmness (B), Soluble solid content (C) and Titratable acidity (D) of strawberries stored at 1°C for 20 d. Vertical bars represent standard error (n = 3).**

**Total anthocyanin content (TAC), total phenolic concentrations (TPC)**

Anthocyanin and phenolic compounds are beneficial phytochemicals that affect the functional properties of strawberry fruits (Giampieri *et al*. 2012). There is an increase in consumers' demand of fresh strawberry fruits due to beneficial properties (Flores-Félix *et al*. 2015). It is therefore critical to consider their changes during storage. Coating treatments and storage time significantly ($p<0.05$) affected the initial total anthocyanin content (50.5 mg $kg^{-1}$ of pelargonidin-3-glucoside) and total phenol content (355 mg $kg^{-1}$ of garlic acid on fresh weight basis) of fresh strawberries during storage (Fig. 3.B. and C.). After 4 d of storage, a sharp increase in anthocyanin was observed in all coated fruits compared to uncoated (Fig. 3. B.). Fruits treated with 50%

AG+ 50% GT had the greatest anthocyanin content than those of other treatments and untreated fruits after 20 d of storage ($p<0.05$). The amount of anthocyanin content of strawberry is dependent on the cultivar, storage temperature and $O_2$ concentration (Cordenunsi *et al*. 2005). Several studies have shown that the biosynthesis of the strawberry fruits have continued during storage (Kalt *et al*. 1999; Cordenunsi *et al*. 2005; Ayala-Zavala *et al*. 2005). However, a slight increase in anthocyanin content for all samples was observed up to 20 d of storage (Fig. 3.B). According to Fig 3.C., the total phenolic contents in all uncoated samples decreased following storage for 20 d (223 mg $kg^{-1}$) but they decreased in coated samples up to 16 d in 25% AG+ 75% GT (252 mg $kg^{-1}$), 50% AG+ 50% GT (278.5 mg $kg^{-1}$) and 75% AG+ 25% GT (271 mg $kg^{-1}$) and then increased up to 20 d. The total phenolic contents decrease at different rates as the storage time increases, significantly ($p<0.05$). However, phenol degradation in control was higher than other coated samples after 20 d (Fig.3.C.). Strawberries coated with 50% AG+ 50% GT maintained higher total phenols (295 mg $kg^{-1}$) compared with other coated treatments at the end of storage. Coating materials stabilize the TSS/ TA ratio in fruits and cause the pH remain at a low level. It is leading to a decrease in enzyme activity of polyphenol oxidase and increase total phenol concentrations (Singha *et al*. 2009). Gol *et al*. (2013) showed that total phenolic contents increased in strawberries during cold storage.

**Antioxidant activity**

Antioxidant activity in coated and uncoated strawberry fruits decreased during cold storage at 1°C (Fig.3.D.). Reducing the rate of antioxidant activity in coated fruits was faster than that of uncoated. The high antioxidant activity was observed in strawberry fruits that were coated with 25% AG+ 75% GT (45.5%), 50% AG+ 50% GT (55.5%) and 75% AG+ 25% GT (50.6%) compared to control (36.5%) after 20 d. As shown in Fig.3.D, coating containing 50% AG+ 50% GT is the most effective treatment to maintain antioxidant activity in strawberry fruits during cold storage. However, aloe vera gel has inherent antioxidant capacity resulted in aloe gel coated fruits retained their antioxidant activity. Previous studies have shown that antioxidant capacity of aloe vera at different stages of development, is due to many active compounds with different degrees of antioxidant capacity (Vieira *et al.* 2016; Wu *et al.* 2006). Ascorbic acid and the total phenolic contents in strawberry fruits could have a significant impact on the antioxidant activity (Kelebek *et al.* 2009; Wang and Lewers 2007). Studies have shown that grapes (Serrano *et al.* 2006) and raspberry (Hassanpour 2015) coated with aloe vera gel had higher antioxidant capacity than uncoated.

**Sensory evaluation**

According to Fig.4. Significant differences ($p<0.05$) were determined in the sensory characteristics of coated strawberries compared to uncoated except for the color score. Scores for all sensorial attributes fall down as the storage time increased, significantly ($p<0.05$). After 20 d, the panelists assigned the highest color, odor, taste and overall scores to strawberry fruits coated with 50% AG+ 50% GT, 75% AG+ 25% GT and 25% AG+ 75% GT, respectively and the lowest score being associated with uncoated samples (Fig. 4.). The odor and texture scores correlated well with the microbial load and firmness values presented in Fig. 1. and Fig. 2.B, respectively. It can be concluded that, 50% GT+ 50% AG treatment as the best coating combination, could keep the sensory attributes of strawberries over the storage period. Garcia *et al.* (2012) reported that sensory characteristics of the strawberries coated with cassava starch had been accepted by consumers up to 12 d compared to uncoated fruits. Benitez *et al.* (2013) showed that the coating of kiwifruit slices with 5% aloe vera gel improved their marketability up to 8 d.

## Conclusion

The results obtained in the present research showed that application of combined edible coating containing aloe vera and gum trgacanth is a new preservation approach for fresh strawberry fruits at 1ºC. Using solution coating containing 50 % diluted aloe vera (1: 3) and 50% gum tragacanth solution (0.6 % w/v), extended the shelf life of fresh strawberries up to 20 d without any side effects on their physicochemical characteristics and sensorial attributes. However, application of combined coating containing aloe vera and gum tragacanth for storage of fresh strawberries is not sufficient for long time storage. This study revealed that for extension shelf life of fresh strawberries, it is necessary to apply another treatment as a new hurdle in addition to coating treatments.

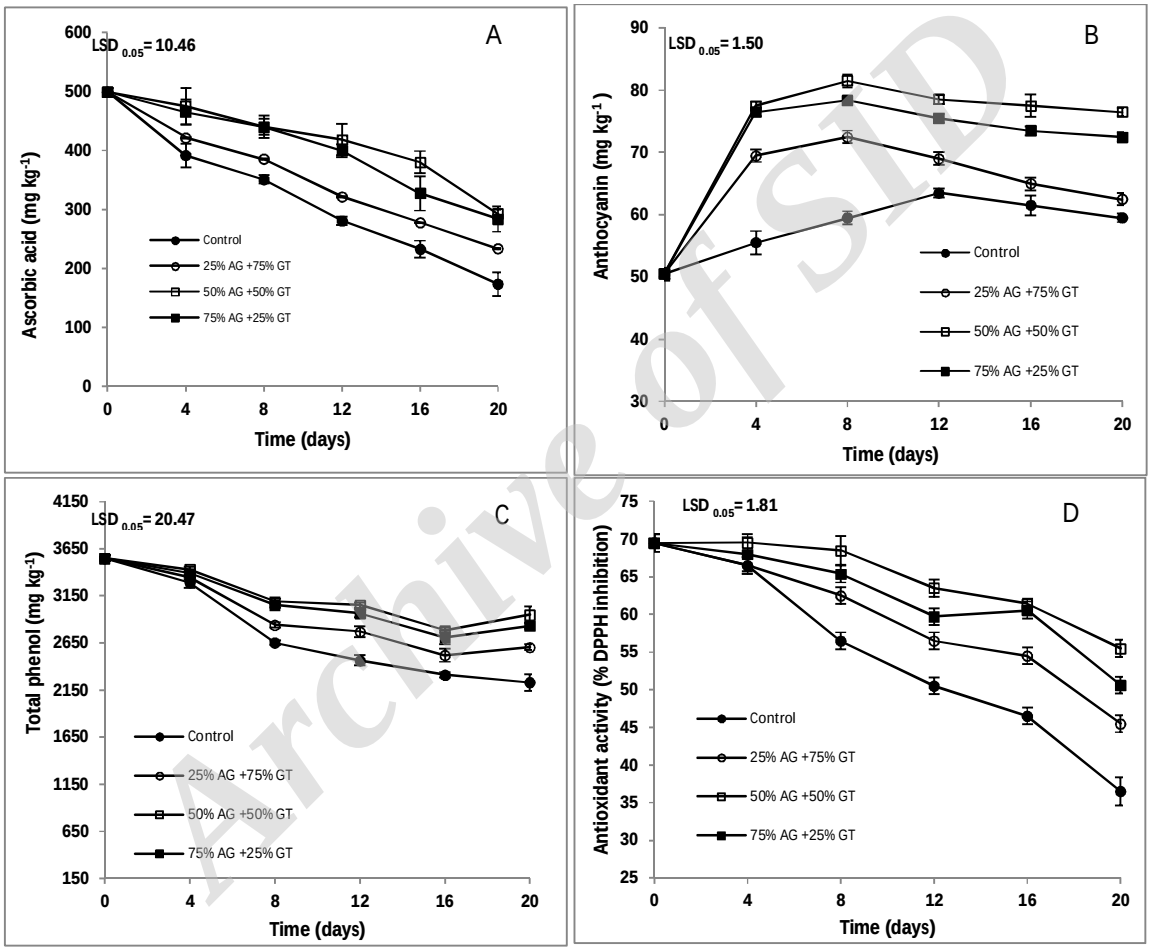


**Fig.3. Effect of mixed coating based on aloe vera (AG) and gum tragacanth (GT) on Ascorbic acid (A), Anthocyanin (B), Total phenols (C) and Antioxidant activity (D) of strawberries stored at 1 °C for 20 d. Vertical bars represent standard error (n = 3).**

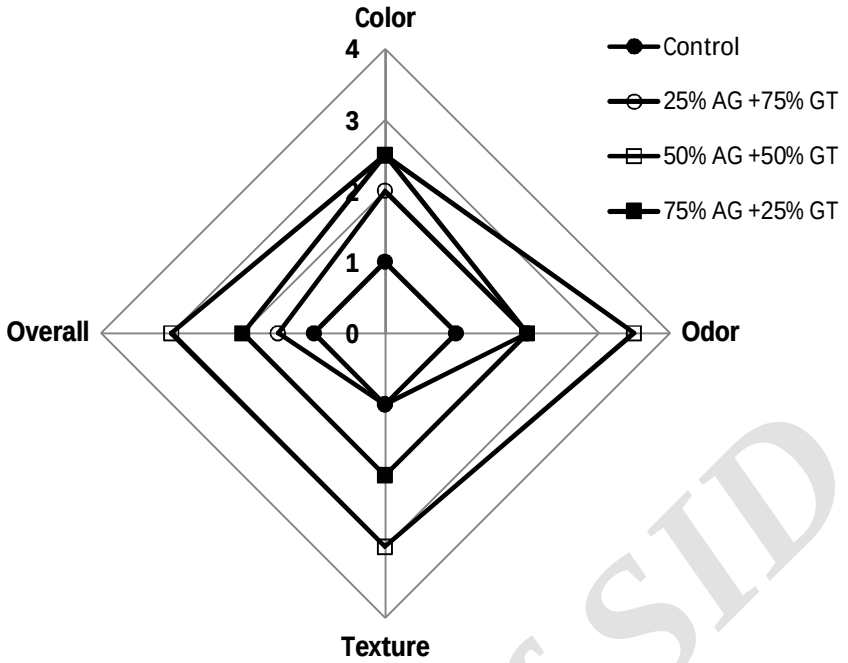


**FIG. 4. Effect of mixed coating based on aloe vera (AG) and gum tragacanth (GT) on the sensory attributes of strawberries after 20 d at 1 ºC.**



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# تاثیر پوشش خوراکی ترکیبی بر پایه صمغ کتیرا و آلوئه‌ورا بر کیفیت پس از برداشت توت‌فرنگی طی انبارداری

آریو امامی‌فر[1*] - سودابه باویسی[2]

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## چکیده

اثرپوشش ترکیبی بر پایه ژل آلوئه ورا و ژل کتیرا بر ویژگی های میکروبی، فیزیکوشیمیایی و حسی توت فرنگی تازه طی 20 روز انبارداری (دمای یک درجه سانتی گراد و رطوبت نسبی 95 درصد) در مقایسه با نمونه بدون پوشش ارزیابی گردید. پوشش ها با مخلوط کردن محلول ژل آلوئه ورا رقیق شده (به نسبت 1:3 وزنی حجمی در آب مقطر) و ژل کتیرا (با غلظت 0/6 درصد وزنی حجمی در آب مقطر) در غلظت های مختلف ( 25% ژل آلوئه ورا + 75% ژل کتیرا، 50% ژل آلوئه ورا + 50% ژل کتیرا و 75% ژل آلوئه ورا + 25% ژل آلوئه ورا + 75% ژل کتیرا) تهیه شدند. پایداری میکروبی (تعداد کپک و مخمر و کل باکتری های مزوفیل هوازی)، خصوصیات فیزیکوشیمیایی(اسید آسکوربیک، کاهش وزن، سفتی، اسیدیته، مواد جامد محلول، محتوی آنتوسیانین، فنل کل و فعالیت ضد اکسایشی) و ویژگی های حسی (رنگ، طعم، بو و پذیرش کلی) نمونه ها پس از 0، 4، 8، 12، 16 و 20 روز از شروع انبار داری در مقایسه با نمونه بدون پوشش (شاهد) ارزیابی گردید. پوشش های حاوی50% ژل آلوئه ورا + 50% ژل کتیرا در مقایسه با نمونه های بدون پوشش به صورت معنی داری ($p< 0/05$) رشد میکروبی، کاهش وزن و تخریب اسید آسکوربیک را در نمونه های توت فرنگی کاهش داده و سفتی بافت، محتوی آنتوسیانین، فنل کل و ظرفیت ضد اکسایشی آن ها را حفظ کردند. همچنین بیشترین امتیاز ویژگی های حسی به توت فرنگی های پوشش داده با 50% ژل آلوئه ورا + 50% ژل کتیرا اختصاص یافت. به هر ترتیب محلول ترکیبی از دو ژل کتیرا و آلوئه ورا به عنوان یک فرمول پوششی مطلوب، علاوه بر خاصیت ضد میکروبی زیاد، از توانایی بالایی در افزایش ماندگاری توت فرنگی تازه برخوردار بود.

**واژه‌های کلیدی**: توت‌فرنگی، آلوئه ورا، صمغ کتیرا، عمر نگهداری

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