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Comparing the Effect of Arabic, Basil Seed and *Salvia Macrosiphon* Gums-Based Coatings on the Shelf-Life of Tomatoes

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ABSTRACT: A novel edible coating containing basil seed gum (0.1, 0.3, and 0.5%), *Salvia macrosiphon* seed gum (0.25, 0.5, and 0.75%), and Arabic gum (10%) at normal pH and pH 5/6 has been used as a postharvest treatment to maintain tomato quality and safety. In this study, the physicochemical properties of tomatoes were investigated during 35 days of storage at 4°C. During storage, coated fruit showed increases in vitamin C retention, reduced weight loss, color changes, and accelerated softening. However, treatment of tomatoes with gum significantly delayed onset of parameters related to loss of postharvest quality, and storability was extended. All the coated samples had increased vitamin C retention compared with controls, with highest contents observed for tomatoes coated in basil seed gum 0.1% and Arabic gum at pH 5.6. In conclusion, basil seed gum 0.1%, *S. macrosiphon* seed gum 0.25 and 0.5%, and Arabic gum at normal pH were the best treatments for maintaining postharvest quality of tomatoes.

Keywords: Arabic gum, basil seed gum, edible coating, *Salvia macrosiphon* gum, tomato

INTRODUCTION

Tomatoes (*Solanum lycopersicum* L.) are among the most consumed fruits in the world, therefore may be considered essential sources of dietary antioxidants (Lenucci et al., 2006). Tomatoes are climacteric fruits that have relatively short postharvest lives due to many physicochemical changes causing loss of quality. As a climacteric fruit, gas, temperature, and humidity adjustment can regulate tomato fruit ripening. Low-temperature storage is needed to preserve freshness and to extend shelf life, leading to a decreased rate of respiration and reducing thermal decomposition. However, chilling injuries may affect the quality of fruits stored below 12.5°C (Bailén et al., 2006; Ali et al., 2010). Controlled atmosphere and hypobaric storage are other approaches that can help extend the shelf-life of tomatoes (Ali et al., 2010). However, these processes are capital intensive and costly to run. Therefore, a cheaper alternative is required to extend postharvest life and keep production costs low. Since gums are obtained from various sources and have a wide range of applications, gum-based edible coatings may be desirable candidates (Ali et al., 2010). An edible coating is a thin layer of edible materials, that forms a coating on a food product. Coatings are applied in liquid form, usually by immersing the product in a solution formed by the structural matrix.

Edible films and coatings can protect food products from moisture migration, microbial growth on surfaces, light-induced chemical changes, and nutrient oxidation. Edible coatings can act as barriers against oils, gases, vapors, and carriers of active substances such as antioxidants, antimicrobials, colors, and flavors (Latifi et al., 2019; Ebadi et al., 2021). These functions enhance the quality of food products, resulting in extended shelf-lives and improved safety (Baldwin, 1994; Pérez-Gago et al., 2010). Development of edible coatings using natural biopolymers presents many advantages for the quality char-

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acteristics of fruits, allowing alternatives with lower costs and more accessible applications than other conservation systems. Consequently, edible coatings may be an effective alternative to synthetic materials in terms of edibility, biocompatibility, nontoxicity, and lower costs (Krochta et al., 1994). Gums are used in foods due to their different beneficial characteristics. Arabic gum or gum acacia is a dried, gummy exudate from the stems or branches of *Acacia* species. It is the least viscous and most soluble of the hydrocolloids, and is used extensively in the industrial sector because of its emulsification film-forming properties (Ali et al., 2010). The genus Salvia (*Labiatae*) comprises more than 700 species, of which 200 grow in Iran. Wild sage seed (*Salvia macrosiphon*) is a tiny rounded seed, which readily swells in water to give mucilage. Gum extracted from these seeds has been shown to have good thickening properties (Javidnia et al., 2005). Basil seed gum is a novel hydrocolloid extracted from *Ocimum basilicum* L. seeds. Basil seed gum has shown promising stabilizing and emulsifying properties, making it a potential functional ingredient for the food industry (Hosseini-Parvar et al., 2010). Many studies have shown that coating has potential to be used as a protective treatment for extending postharvest qualities of fruits and vegetables such as tomatoes (Zapata et al., 2008; Ali et al., 2010), apples (El-Anany et al., 2009), strawberries (Ribeiro et al., 2007), and mangos (Chien et al., 2007). However, no published studies have yet been conducted on the application of basil gum and wild sage seed as edible coating for increasing the storage life of tomatoes. Hence, this study aimed to evaluate the physicochemical properties of coated tomato during storage.

MATERIALS AND METHODS

Materials

Tomatoes (*S. lycopersicum* L. var. Money Maker L.) was collected from Noshahr city (Mazandaran, Iran) in April 2014. Basil and *S. macrosiphon* seeds were purchased from a reputable local market in Chaloos (Mazandaran, Iran). Arabic gum was purchased from Scharlau (Barcelona, Spain). Glycerol, 2,6-dichlorophenolindophenol, and yeast glucose chloramphenicol culture medium were purchased from Merck KGaA (Darmstadt, Germany). All other chemicals used in this study were of analytical grade and were purchased from chemical suppliers.

Basil seed extraction

Basil seed gum was extracted following the methods by Razavi et al. (2009). To prepare gum mass, seeds were soaked in water at 68°C in a ratio of 1:65. During soaking, a row mixer stirred the mixture for 20 min at 1,000 rpm. Gum was separated from the swelled seeds by passing the seeds through an extractor (JC 700P, Pars Khazar, Rasht, Iran) with a rough rotating plate that scraped the gum layer on the seed surface. The separated gum was collected, and the residual gum adhered to the seeds was immersed in water with the rotating extractor. The gum collected from the different stages was mixed, filtered, and dried by a vacuum oven at 50°C. Finally, the dried extracted gum was ground, packed in plastic bags, and stored in dry and cool condition.

S. macrosiphon extraction

S. macrosiphon seed gum was extracted from whole seeds using distilled water (water to seed ratio of 1:51) at pH 5.5. The gum from swelled seeds was separated by passing the seeds through a laboratory extractor (Model 412, Pars Khazar). Crude gum was collected, and residual seeds were immersed in the remaining water in two stages, according to the water-to-seed ratio proposed for each run, and passed through the extractor again. The collected crude gum from the different stages was mixed, filtered, and dried overnight in a forced convection oven (Model 4567, Kimia Pars, Tehran, Iran) at 70°C. The dried gum was ground, filtered, and used for analysis (Bostan et al., 2010).

Preparation of hydrocolloid suspensions

Coating solutions were prepared according to the method of Ali et al (2010). Basil seed gum and *S. macrosiphon* gum were separately mixed and distilled in a weight/volume ratio. Suspensions were mixed for 60 min at 20°C, then glycerol 1% was added to increase the strength and flexibility of the coating solutions. The Arabic gum solution was prepared in two ways: (1) without maintaining the pH; (2) maintaining the pH 5.6 by 1 N NaOH, following by similar stages as those used in the preparation of the other solutions. The concentrations of the prepared solutions were 0.1, 0.3, and 0.5% for basil seed gum, 0.25, 0.5, and 0.75% for *S. macrosiphon* seed gum, and 10% for Arabic gum.

Tomato coatings

Red tomatoes of the same shape and size, without any mechanical damage and pathogenic contamination, were purchased. Tomatoes were washed with distilled water, rinsed, and dried at an ambient temperature. Then, tomatoes were soaked in the prepared solution for 4 min at 20°C until the whole fruits were coated. Coated fruits were dried at ambient temperatures for 60 min, packaged in polyethylene at 7°C, with a humidity of 85% to 90%, and stored for 35 days. Control sample were also prepared in a similarly manner but without coatings. All tomatoes were analyzed for physicochemical and microbial properties at intervals of 7 days (Ali et al., 2010).

Weight loss determination

Tomatoes were weighed at day 0 and at the end of each storage interval. Total weight loss during that storage interval was calculated as the difference between the initial and final weights, calculated as percentages of a fresh weight based on the standard Association of Official Analytical Chemists (AOAC) method (Helrich, 1990).

Acidity

Titratable acidity of aliquots was determined by titrating with 0.1 N NaOH until a pH of 8.1 was reached. Titratable acidity was expressed as mg of citric acid per 100 g of fresh fruit.

Determination of pH

An industrial juicer (G100, Hellal, Tehran, Iran) was used to extract the tomato juice. To determine the pH of the juice, a pH meter (Model 691, Metrohm AG, Herisau, Switzerland) was used. The juice was poured into beakers containing pH meter electrodes to record the pH of the juice.

Determination of total soluble solids (TSS)

Tomatoes were ground in a blender, and the juice was used to determine the concentration of soluble solids (Brix) using a Digital Refractometer (Model PR-32, Atago, Tokyo, Japan).

Determination of ascorbic acid content

Ascorbic acid contents were determined following the method of AOAC (Helrich, 1990). Ground samples were weighed into 50 mL tubes, mixed with 25 mL of 2.5% *m*-phosphoric acid using a vortex mixer for 1 min, and centrifuged for 20 min at 48°C and 3,000 *g*. The supernatant was filtered through a cheesecloth into 50 mL volumetric flasks, and ascorbic acid contents were determined using 2,6-dichlorophenolindophenol titration.

Statistical analyses

All analyses were carried out in triplicate. Data were subjected to analysis of variance (ANOVA). Sources of variation were storage time and treatment. Mean comparisons were performed using Duncan's post-hoc tests to examine if differences between treatments and storage times were significant at $P<0.05$. All analyses were performed using SPSS software package version 16.0 for Windows (SPSS Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

Weight loss measurements

The effect of Arabic gum, basil seed gum, and *S. macrosiphon* gum coating on weight loss of tomatoes stored for 35 days is shown in Fig. 1. Weight loss of control fruits significantly ($P<0.05$) increased with storage time, reaching 2.8% at day 35 (Fig. 1). Coated fruits showed less weight loss during storage than controls, and with only gradual increases during the storage period. The results indicated that gums significantly ($P<0.05$) reduced weight loss and acted as a barrier against water loss. The primary mechanism of weight loss from fresh fruit and vegetables is vapor pressure from different locations (Yaman and Bayoındırlı, 2002), although respiration also causes weight reductions. The reduction in weight loss was probably due to the effects of the coating as a semi-permeable barrier against O_2, CO_2, moisture, and solute movement, thereby reducing respiration, water loss, and rates of oxidative reactions (Baldwin et al., 1999).

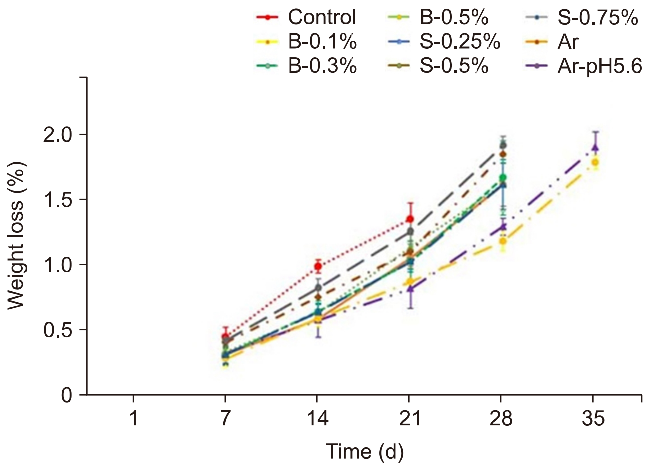

Fig. 1. Changes in weight loss of tomatoes with different coatings during the 35 days of storage. Results are presented as mean±standard deviation. Ar, Arabic gum; B, basil seed gum; S, *Salvia macrosiphon* seed gum.

These results are in agreement with findings from Srinivasa et al. (2006) on tomatoes and bell peppers packaged in cartons covered with eco-friendly chitosan film or synthetic petroleum-based low-density polyethylene (LDPE) film. In this study, chitosan and LDPE films extended the storage life of both tomatoes and bell peppers through reducing water loss and modifying the internal atmosphere. Similar results were reported by Lim et al. (2011), who used gelatin, carboxymethylcellulose, and soy protein isolates as edible films at three different concentrations for coating sweet cherry (*Prunus avium* L.) fruits. This study reported that coating significantly decreased moisture loss from coated fruits, decreasing their weight loss (Lim et al., 2011). Martínez-Romero et al. (2006) observed similar results when they coated sweet cherry fruits using aloe vera as a novel edible coating. Another study by Jafarizadeh Malmiri et al. (2011) showed the effect of three edible coating formulations on the peel surface of mature green bananas, which were stored at 26°C with relative humidity ranging from 40% to 50%. The authors showed that coated bananas with 1.5% sodium carboxymethyl cellulose had negligible weight loss and TSS contents (Martínez-Romero et al., 2006). Furthermore, a study by Saekow et al. (2019) indicated that applying carboxymethyl cellulose coatings combined with ZnO nanoparticles to tomatoes decreases the rate of weight loss. Corn starch and carnauba wax coatings have also been reported to be effective moisture barriers and to reduce weight loss of coated tomatoes (Fitch-Vargas et al., 2019). In addition, coating tomatoes with red algae and brown algae decreased weight loss during a 28 day storage period (Banu et al., 2020), and Khalil et al. (2020) indicated that glycerol, starch, and gelatin amalgamated with gamma-irradiated *Lactobacillus* bacteria as an edible coating gave better results than untreated fruits, such as diminishing weight loss. Moreover, a study by Ruiz-Martínez et al. (2020) showed that edible coatings of candelilla wax with *Flourensia cernua* extract reduces weight and loss of firmness of tomatoes, and Zhu et al. (2019) revealed that nano-SiOx/chitosan complex coatings result in lower weight loss of green tomato compared with chitosan and controls. Finally, a study by Sganzerla et al. (2021) showed that carboxymethyl cellulose-based film enriched with blackberry anthocyanin-rich extract helps preserve cherry tomatoes and helps maintain their weights.

Acidity evaluation

The control tomatoes had a slightly higher acid content compared with the coated fruits (Table 1), although the rates of acid content changes did not significantly differ ($P>0.05$). However, the difference between the acid contents of the coated and control fruits was significant during storage ($P<0.05$). In previous studies, Yaman and Bayoındırlı (2002), Dong et al. (2004), and Durrant and Dong (2004), reported slow rates of decreasing acidity for litchi, cherries, and peach. Organic acids are substrates for many enzyme-catalyzed reactions during aerobic respiration in plant cells, and reductions in acidity may be expected as a result of such activity during the ripening process, thus making the fruits taste relatively more sweet. A decline in acidity indicates increased maturation; thus, coating delayed fruit maturation/ripening. Citric acid is one of the primary substances of respiration; during the storage period, total acidity decreases due to oxidation, but the acidity in the fruit increases. However, another experiment on organic papaya fruit showed that gums helped preserve the fruit acids compared with control treatment (Eskandari et al., 2014). In a study by Fitch-Vargas et al. (2019), tomatoes coated with corn starch and carnauba wax had a lower percentage of titratable acidity than control fruit, and in a study where seaweeds, namely red algae and brown algae, were used to coat tomatoes to control total acidity, lowest acidities were reported for control samples (Banu et al., 2020). In addition, another study by Khalil et al. (2020) using irradiated *Lactobacillus paracasei* cell-free supernatants combined with glycerol, starch, and gelatin as edible coatings for control samples had lower percentages of titratable acids than coated samples. Furthermore, Ruiz-Martínez et al. (2020) showed that coating tomatoes with candelilla wax containing *F. cernua* extract resulted in minimal percentages of titratable acidity. Moreover, a study by Sganzerla et al. (2021) reported that carboxymethyl cellulose-based coatings enriched with blackberry extract did not alter acidity during storage and, therefore, the parameter for all the samples was the parameter gradually decreased during storage.

pH measurements

The pH depends on the concentration of hydrogen ions in the solution. The pH of tomatoes was increased during storage (Fig. 2). Since coated fruits showed minor variation in titratable acidity, the associated variations in their pH values were also relatively low. Control tomatoes had a higher pH than coated fruits at any given time, confirming previous results from Maftoonazad and Ramaswamy (2005) showing increasing pH values in avocados coated with methyl cellulose-based. The rates of pH increases was also higher in control samples than in coated fruits. Toğrul and Arslan (2004) showed increases in pH values of samples with different coating during storage. Furthermore, Fitch-Vargas et al. (2019) showed that carnauba

Table 1. Changes in acidity of tomatoes with different coatings during 35 days of storage

Day of storage	Control	Ar-pH Normal	Ar-pH 5.6	B-0.1%	B-0.3%	B-0.5%	S-0.25%	S-0.5%	S-0.75%
1	0.48±0.02^{a}	0.46±0.01^{a}	0.44±0.04^{a}	0.47±0.01^{a}	0.47±0.03^{a}	0.46±0.03^{a}	0.44±0.02^{a}	0.47±0.03^{a}	0.48±0.02^{a}
7	0.42±0.01^{b}	0.42±0.00^{b}	0.42±0.04^{ab}	0.45±0.02^{ab}	0.44±0.02^{ab}	0.43±0.03^{ab}	0.41±0.01^{b}	0.43±0.03^{ab}	0.43±0.02^{a}
14	0.37±0.01^{c}	0.39±0.01^{bc}	0.40±0.04^{ab}	0.43±0.02^{bc}	0.41±0.03^{bc}	0.40±0.03^{ab}	0.38±0.01^{c}	0.39±0.02^{bc}	0.43±0.06^{b}
21	0.30±0.00^{d}	0.35±0.03^{c}	0.38±0.03^{abc}	0.41±0.01^{cd}	0.38±0.02^{cd}	0.37±0.03^{bc}	0.35±0.01^{d}	0.34±0.02^{cd}	0.39±0.05^{bc}
28	–	0.32±0.02^{d}	0.35±0.30^{bc}	0.39±0.01^{de}	0.34±0.02^{d}	0.33±0.03^{c}	0.30±0.00^{e}	0.29±0.02^{d}	0.34±0.04^{c}
35	–	–	0.32±0.03^{c}	0.36±0.01^{e}	–	–	–	–	–

Results are presented as mean±standard deviation.
The same letters (a-e) in each row indicate that there is no significant difference ($P<0.05$).
Ar, Arabic gum; B, basil seed gum; S, *Salvia macrosiphonseed* gum.

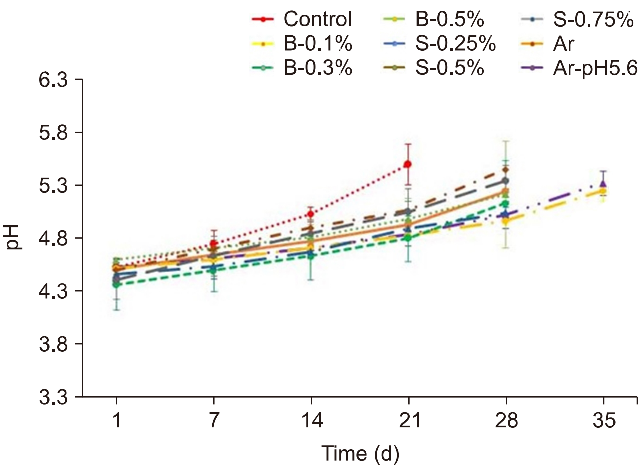

Fig. 2. Changes in pH of tomatoes with different coatings during 35 days of storage. Results are presented as mean±standard deviation. Ar, Arabic gum; B, basil seed gum; S, *Salvia macrosiphon* seed gum.

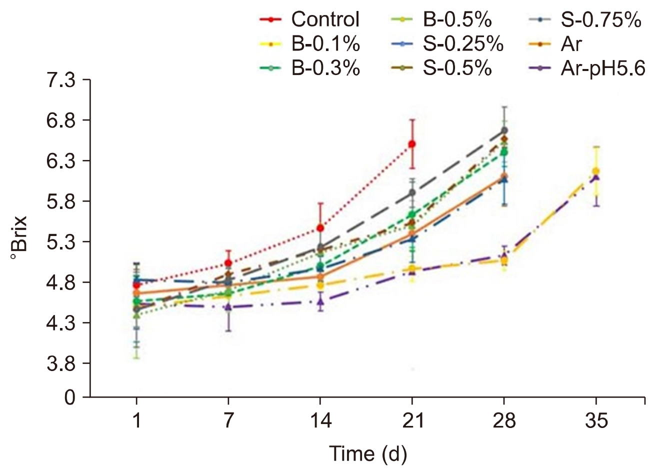

Fig. 3. Changes in total soluble solids of tomatoes with different coatings during 35 days of storage. Results are presented as mean±standard deviation. Ar, Arabic gum; B, basil seed gum; S, *Salvia macrosiphon* seed gum.

wax is a more effective coating for tomatoes than corn starch for inhibiting pH growth during 20 days of storage, however, both coatings functioned better than the control sample. Moreover, Khalil et al. (2020) revealed that glycerol, starch, and gelatin-based coatings enriched with irradiated *L. paracasei* cell-free supernatant for did not affect the pH of coated tomatoes compared with control samples during 14 days of storage. In a study where tomatoes were coated with candelilla wax, the pH was higher than in control tomatoes, and enriching the coating with *F. cernua* extract surged the pH to the minimum at the end of the storage period (Ruiz-Martínez et al., 2020). In addition, in a study where cherry tomatoes were coated with carboxymethyl cellulose-based coating containing blackberry extract, samples coated with the highest percentage of the extract had the lowest pH at the end of 15 days storage period (Sganzerla et al., 2021).

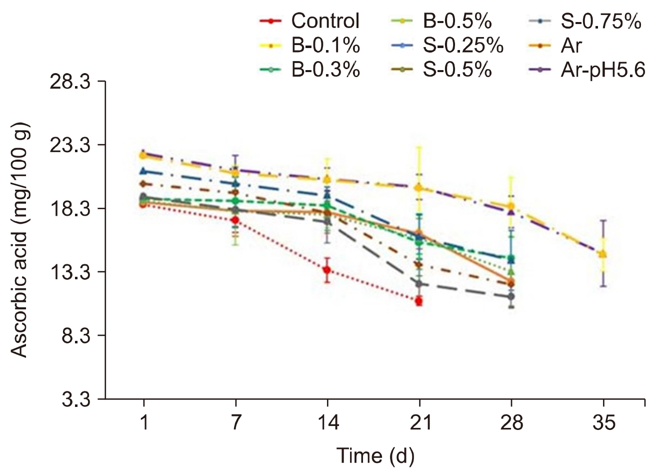

Fig. 4. Changes in ascorbic acid contents of tomatoes with different coatings during 35 days of storage. Results are presented as mean±standard deviation. Ar, Arabic gum; B, basil seed gum; S, *Salvia macrosiphon* seed gum.

TSS measurements

TSS are an indirect indication of the level of soluble sugars and, therefore, sweetness, and are an important quality characteristic of most fruits since the value will affect the fruit's flavor and marketability (Shwartz et al., 2009). In this study, TSS decreased during storage, with the amount of soluble solids reducing during respiration (Fig. 3). Ali et al. (2010) reported that use of Arabic gum at 10% delayed changes to the concentration of soluble solids compared with uncoated fruits, similar to the result of the current study. Other studies have reported a gradual decrease in TSS with storage time (Maftoonazad and Ramaswamy, 2005). For example, Fitch-Vargas et al. (2019) showed that during a 20 days storage period, TSS of tomatoes coated with corn starch and carnauba wax did not significantly differ from controls until the second half of the storage period, with all samples showing significant differences on the last day of this period. In another study, coating tomatoes with high concentrations of red and brown algae led to high soluble solids contents during 28 day storage periods (Banu et al., 2020). Furthermore, in the study by Khalil et al. (2020), the TSS percentage increased proportionally with increased storage period, and at each checkpoint untreated tomatoes had higher TSS values than tomatoes coated with glycerol, starch, and gelatin. In addition, in the study of Ruiz-Martínez et al. (2020), a gradual increase in soluble solids concentration of tomatoes was observed during the storage period, and samples coated with candelilla wax-based coating enriched with *F. cernua* extract had the highest TSS. Moreover, the study of Zhu et al. (2019) revealed that nano-SiOx/chitosan complex film delays loss of TSS.

Ascorbic acid content

Tomatoes are important sources of vitamin C, which varies between 10 and 60 mg. Polyphenol oxidase enzymes degrade the fruit, and the content of ascorbic acid decreases during storage. The ascorbic acid (vitamin C) content of coated and uncoated tomatoes decreased during storage, with highest levels of ascorbic acid observed in those coated with 0.1% basil gum (Fig. 4). In tomatoes, ascorbic acid content increases with maturity and ripening; however, once the fruit is fully ripe, the ascorbic acid content starts to decline. The slower increases in ascorbic acid contents of coated fruit suggests that the coating slows down but does not prevent synthesis of ascorbic acid during ripening. A similar effect on slowing down the increase in ascorbic acid during ripening of tomatoes has been reported with high CO_2 storage atmospheres.

In conclusion, edible coatings improved certain quality attributes of tomatoes. Arabic gum, basil seed gum, and *S. macrosiphon* seed gum increased vitamin C retention of tomatoes compared with uncoated tomatoes, and helped maintain fruit firmness throughout storage. Combining these gums could be recommended for commercial purposes as an alternative to postharvest chemical treatments, helping to combat the high economic costs and improve the physicochemical properties of tomatoes. In a previous study, while control tomatoes had the lowest ascorbic acid content, tomatoes coated with carboxymethyl cellulose and carboxymethyl cellulose combined with ZnO-nanoparticles had the second-highest and highest contents of ascorbic acid, respectively (Saekow et al., 2019). Furthermore, there is a drastic decrease in the ascorbic acid content of control tomatoes during the storage period; in another study, tomatoes coated with high concentrations of red and brown algae had higher ascorbic acid contents compared with other tomatoes (Banu et al., 2020). Another study revealed that tomatoes coated with glycerol, starch, and gelatin-based coatings amalgamated with gamma-irradiated *Lactobacillus* bacteria had, in general, high ascorbic acid concentrations during 14 day storage periods (Khalil et al., 2020).

AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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