

Influence of *Aloe vera* L. Based Ascorbic Acid and Lactic Acid Edible Coatings on Quality and Shelf Life of Tomato

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ABSTRACT

This study was done to evaluate the effect of edible coatings based on *Aloe Vera* L. (AV) in combination with ascorbic acid and lactic acid on the postharvest life and quality of tomato. Several coatings based on different natural components such as gum Arabic, carnauba, mineral oil, etc. have shown an increase in the shelf life with better retention in postharvest quality. Two edible coatings of natural *Aloe vera* gel (10%) along with Ascorbic Acid (AA; 1%) and Lactic Acid (LA; 1%) were applied to mature tomatoes as an edible coating and stored at room temperature (25-29°C) and 82-84% Relative Humidity (RH) for 30 days. After application, weight loss, total Titratable Acidity (TA), Soluble Solids Content (SSC), ascorbic acid content, pH value, total phenolic content, total antioxidant activity, and decay percentage were measured at 0, 7, 14, 21, and 30 days. Compared with untreated tomato, coated ones exhibited a significant ($P \leq 0.05$) delay in weight loss and higher retention of SSC, vitamin C, and titratable acidity. Between the two coatings applied to tomato, AV+1% AA+1% LA coating was found to be the most effective in delayed ripening and maintaining the postharvest losses. Results obtained in this study support using AV and AA+LA edible coating as an effective alternative to preserving tomato, delay ripening processes, and extend shelf life.

Keywords: *Aloe vera* gel; Antioxidant activity, *Lycopersicon esculentum*, Post-harvest quality.

INTRODUCTION

Tomato (*Lycopersicon esculentum*) is one of the most cultivated, consumed and important vegetables worldwide (Dursun *et al.*, 2019). Tomatoes are a rich source of fiber, vitamins A, C, lycopene and epidemiological studies indicate that increased consumption of tomato lycopene is related to a lower occurrence of cardiovascular disease and certain types of cancers (Beckles, 2012). There is a growing consumer concern about the eating quality of tomatoes (Jürkenbeck *et al.*, 2019). Tomato is a climacteric fruit and has a relatively short postharvest life since, after harvest, many physical and biological

factors including postharvest diseases, increased ripening, and transpiration affect quality loss (Ali *et al.*, 2010; Ghaderi *et al.*, 2018). In tropical regions where the temperature is high, the main factors that influence the postharvest storage life of tomato are increased respiration and ethylene production rates which results in faster ripening and decline in quality (Ali *et al.*, 2010). During mass transpiration of water, vapor moves from the product to the environment, which results in a weight loss of the produce affecting storage quality (de Jesús Salas-Méndez *et al.*, 2019). One of the major problems of tomatoes during storage, distribution, and ripening is softening, since it increases vulnerability to damage. These

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factors decrease the postharvest shelf-life of tomato and cause economic loss over time (Vieira *et al.*, 2016; Yousefi Javan and Gharari, 2018). For these constraints, the potentiality of different techniques has been studied and applied to increase the shelf life of fruits and vegetable products. Generally, ripening of tomato is maintained using gas, temperature, and humidity, which are responsible for freshness and storage period as they reduce the rate of respiration and thermal decomposition and ultimately spoilage. The massive production of tomato during the harvest time and lack of efficient post-harvest processing, preservation and storage techniques leads to rapid spoilage (Ameyapoh *et al.*, 2008). However, storage below 12.5°C causes chilling injury and affects the quality of the produce. The storage life of tomatoes can be extended by a controlled atmosphere and hypobaric storage, but these processes are costly (Beckles, 2012). The use of natural constituents as a cheaper alternative for both extending postharvest shelf life and keeping production costs low is investigated and developed in recent times (Ali *et al.*, 2010). The needs for high-quality storage technologies without harmful effects have accentuated the notion of using the natural element as edible coatings to extend the shelf life of fresh products. Edible coatings create an additional wall that modifies the atmosphere, acting against O₂, CO₂, moisture, solute movement, delays rate of respiration, oxidation, and establishes the ability to maintain product quality and extending the shelf life of fresh food (Valverde *et al.*, 2005, Martínez-Romero *et al.*, 2006). These coatings also showed reduced microbiological proliferation in the food surface (Dutta *et al.*, 2009). A model coating is well-defined as an efficient and effective system for the reduction of degradation of quality attributes in the postharvest storage period and decreases rates of loss without causing microbiological spoilage to lengthen shelf-life of fruits and vegetables (Raghav *et al.*, 2016). For better microbial stability, appearance and texture,

different functional components such as nutraceuticals, antioxidants, firming agent, preservatives, etc. can be added to coating materials (Cerqueira *et al.*, 2009; Vieira *et al.*, 2016).

Aloe vera (*Aloe barbadensis* Miller) belongs to the family Liliaceae, and is a rich source of medicinal, antimicrobial, and antioxidant agents such as phenolic compounds, carbohydrate polymers, organic acids, fibers, vitamins, amino acids, and mineral salts. Therefore, it has a wide range of use in food, pharmaceutical and cosmetic industries (Rodríguez *et al.*, 2010; Kahramanoğlu *et al.*, 2019). In the past few years, *Aloe vera* used as a novel edible coating has captured much attention for safe and environmentally friendly postharvest treatment (Odriozola-Serrano *et al.*, 2008 Valverde *et al.*, 2005). *Aloe vera* concentrations used in these studies varies depending on the produce. These studies have proven that respiration and ethylene production rate, weight loss, and softening are reduced by coating application. Moreover, aloe gel coating using a total solids content of 1.1–1.2% have been proved to maintain physicochemical factors such as color and firmness in apple slices (Chauhan *et al.*, 2011). The gel treatments as edible coatings have shown potentiality to maintain postharvest quality with several fruit commodities such as sweet or sour cherry (Martínez-Romero *et al.*, 2006), Hayward kiwifruit (Benítez *et al.*, 2013), nectarine (Ahmed *et al.*, 2009), mangoes (Dang *et al.*, 2008), apples (Ergun and Satıcı, 2012), table grape (Valverde *et al.*, 2005; Serrano *et al.*, 2006), strawberry (Sogvar *et al.*, 2016), blueberry (Vieira *et al.*, 2016), orange fruit (Rasouli *et al.*, 2019), and papaya (Mendy *et al.*, 2019).

Components similar to essential oils, acetic acid, and ascorbic acid were incorporated with *A. vera* coatings and showed increased activity (Sogvar *et al.*, 2016). As an antioxidant, Ascorbic Acid (AA) reduces vitamin C loss and can be added to the edible coating material. Antimicrobial properties of AA on fresh-cut

fruit such as papaya (Tapia *et al.*, 2008) have been reported.

This work aimed to study the consequence of *A. vera* incorporated with ascorbic acid and lactic acid as an edible coating on the alteration in physicochemical factors linked to quality throughout storage and role in prolonging the shelf life of tomato.

MATERIALS AND METHODS

Plant Material

Tomatoes (*Lycopersicon esculentum*) harvested at the mature green stage were procured from a native farmer in Sylhet, Bangladesh. At the laboratory, tomatoes were visually categorized based on consistency in size, shape, and color, the absence of injuries, blotches, and malady. Tomatoes were divided into three batches of control, only AV coated, and AV+AA+LA coated batch. A total of 60 tomatoes were taken containing 20 tomatoes in each batch. The procured tomatoes were washed thoroughly with running water and exterior dried before application of the coating.

Aloe vera (AV) Coating Preparation, Treatment, and Storing

The *Aloe vera* gel coatings were prepared through a slight modification of the method followed by Brishti *et al.* (2013) *Aloe vera* leaves were collected from Natore district, Bangladesh. After a thorough wash with warm (40°C) tap water, the leaves were divided longitudinally, and the colorless tissue was scratched out, liquefied in a food-grade blender (HJ-H176P, Malaysia) at maximum speed for 10 seconds and homogenized. The liquid acquired was Aloe Gel (AG; 100%). The liquid was pasteurized at 70°C for 45 minutes, followed by immediate cooling at ambient temperature. To increase coating ability, 1% gelling agent was used for thickening. To enhance the plasticizing effect, 2% glycerol was added.

Oleic acid was added to avoid precipitation; for uniform dispersion, an antimicrobial, namely, Cinnamaldehyde was added alongside oleic acid. The solution was then filtered after adding water to form a 10% AV solution.

The solution was then divided into half, and in one solution, 1% LA and 1% AA were added. The coating application was accomplished by dipping the samples in the corresponding liquid solution for 10 minutes. Later, all fruits were air-dried at room temperature for 1 h, then placed in the tray. Four tomatoes from each batch were sampled at 0, 7, 14, 21 and 30 days of storage.

Physicochemical Analyses of Tomato

Weight Loss Percentage

Tomato samples were weighed using an electronic analytical balance (AY 220, shimadzu Corporation, Japan) at day 0 and at the end of each storage interval for 30 days. Weight loss was measured by taking initial and final weight differences of samples and expressed as a percentage.

pH, Total Soluble Solids (TSS) and Total Titratable Acidity (TTA)

At every 7 days of intervals, except 30th days, three fruits per treatment were analyzed. The samples were grounded in a blender (HJ-H176P, Malaysia) after cutting into small pieces. To determine the pH of each treated sample, a potentiometer (Hanna Instruments Inc., Romania) was used. A digital refractometer (Brix 0–32%, Atago Co Ltd) at 20°C was used to determine TSS according to the AOAC method (932.14) and the results were recorded as %. Then, a filter paper (Whatman No. 1) was used to filter the grounded mixtures. To determine TA, 10 mL of pulp from each sample was taken and phenolphthalein (1%, 2 drops) was added and titrated with 0.1 N NaOH



(AOAC, 1990). Results were shown in percent of Citric Acid (% CA).

Vitamin C Assay, Total Phenolic Content and Antioxidant Activity (AA)

Dye 2, 6-Dichlorophenolindophenol (DCPIP) visual titration method by Ranganna (2004) was used to estimate AA contents as mg per 100 gram of fresh weight. A slightly modified colorimetric method (Singleton *et al.*, 1999) by the Folin-Ciocalteu reagent was used to determine total phenols. Tomato samples were centrifuged at $2,700\times g$ for 15 minutes and filtered through Whatman No 1 filter paper. Afterward, 0.5 mL of the extract was mixed with 0.5 mL of Folin-Ciocalteu reagent and 10 mL of saturated Na_2CO_3 solution was added after 3 minutes. The absorbance was measured at 725 nm after allowing the sample to stand for 1 hour. By comparing the absorbance of the samples with standards, concentrations were determined. Results were expressed as gallic acid equivalents per kilogram of fresh weight (mg kg^{-1}). DPPH free radical scavenging assay was performed by taking 100 μL of tomato extract mixed carefully with methanolic 2 mL of freshly prepared 0.1 mmol L^{-1} DPPH solution. The absorbance was measured in a UV spectrometer (T60 U, PG Instruments LTD) at 517 nm. Blank was prepared by Methanol (100 μL) without the extract. The scavenging ability of the DPPH radical was calculated by the following formula:

$$\text{DPPH-scavenging effect (\%)} = [1 - (A_{517, \text{sample}} / A_{517, \text{blank}})] \times 100 \quad (1)$$

Decay Percentage

The decay of treated and untreated samples was determined as the number of the decayed samples divided by the initial number of all sample and the result was multiplied by 100 (El-Anany *et al.*, 2009)

Statistical Analysis

Triplicate evaluations were performed and means were expressed as the results. Significance in differences between samples for all parameters was calculated using a two-way ANOVA. Statistical analyses were carried out using SPSS. The chosen p-value was $P \leq 0.05$.

RESULTS AND DISCUSSION

Weight Loss

The results for all tomato samples showed increased weight loss as the time of storage increased (Figure 1-a; $P \leq 0.05$) and significant differences were found. AV+AA+LA-treatments prevented more weight loss than AV alone. Tomatoes not coated had a statistically higher loss in mass compared to tomato coated during the storage time. The natural transpiration process is the main reason for this weight loss tendency during storage. The coating reduces respiration, water loss, and oxidation reaction rates because it creates a semi-permeable barrier against gas and moisture movement (Vieira *et al.*, 2016). Similar results were observed when tomatoes were treated with gum Arabic (Ali *et al.*, 2010), *Aloe vera* gel treated “Arctic Snow” nectarines (Ahmed *et al.*, 2009) and aloe gel treated sweet cherries (Martínez-Romero *et al.*, 2006), 33% gel treated table grapes (Valverde *et al.*, 2005) and in 10% gel treated ‘Granny Smith’ apples (Ergun and Satici, 2012). The greatest effect observed on the reduction of weight loss was in the combinations of AA+LA with AV.

SSC, pH and Titrable Acidity (TA)

A gradual increment in SSC was found during the total storage time Figure 1-b. The soluble solids, however, were significantly higher in control tomato and lowest SSC

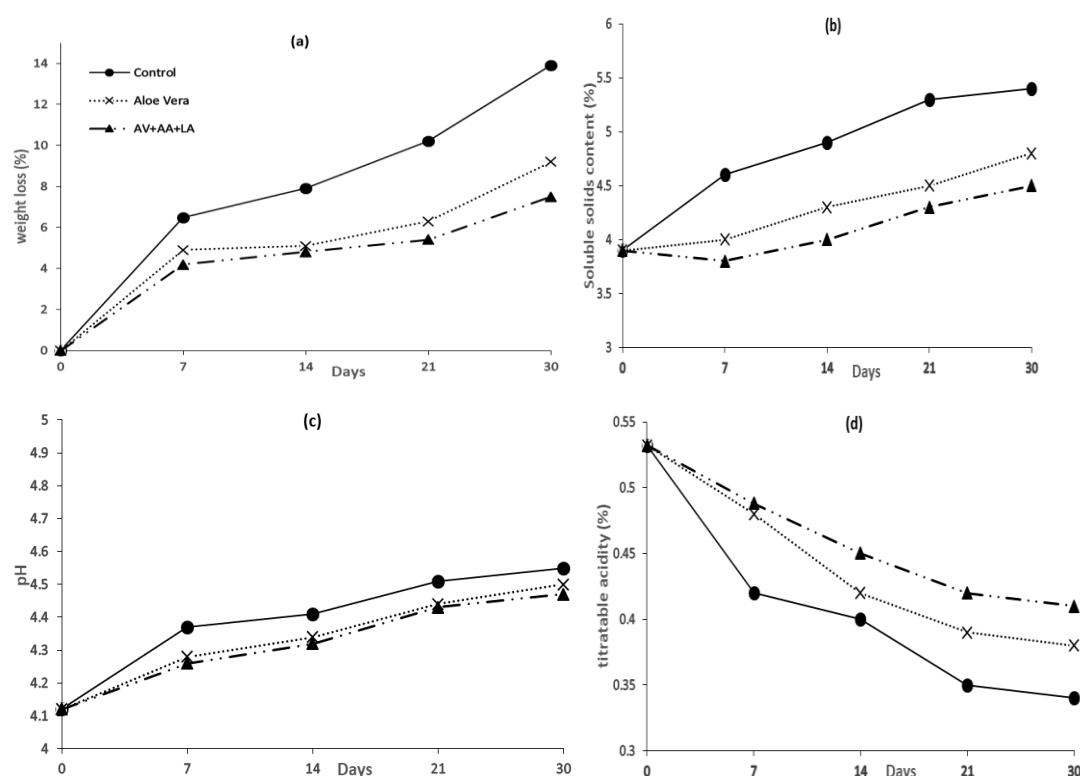


Figure 1. Coatings effect on: (a) Weight loss (%), (b) Soluble solids content (SSC) (%), (c) pH value, and (d) Titratable Acidity (TA) of tomato during 30 d storage (25 -29°C and 82-84% RH).

was found in AV+AA+LA coated tomato. The lowest SSC was observed in tomato coated with AV+LA+AA.

This indicates that the bio preservative coatings provided a semi-permeable layer on the samples to reduce O₂ production or elevates CO₂ and subdues ethylene production by modifying the internal atmosphere. Results similar to this were found in tomato coated with mango kernel and tomato coated with almond gum trees exudate (Nawab *et al.*, 2017).

Results indicate a pH increase in all the samples, though the untreated tomato showed a higher increase than treated samples. The reason behind pH value increment is that, during the time of storage, the acid disintegration happens as respiration goes on. Fruit taste quality is greatly influenced by the acid change. While tomato ripened, the major amounts of acids found were citric acid and malic acid. The increase in the pH of tomato with maturation reported

here was in the range reported by other studies (Fernández-Ruiz *et al.*, 2004)

The values of titratable acidity of tomato samples decreased with increased storage period (Figure 1-d), and the value for AV+AA+LA treated tomato compared to the control was significantly different, with a maximum reduction for uncoated fruit. The pH value was inversely proportional to the TA value. The reduced TA value in the control tomato in comparison with treated tomato indicates delayed ripening effect of the coating by creating a barrier and reducing the rate of respiration. Climacteric agricultural products use organic acids as primary substrates for the respiration process, and coating prevents the utilization of these acids while reduction is expected for respiring produces (El-Anany *et al.*, 2009). This retains the firmness and retards metabolic processes that increase the storage period of tomato. Modified Atmosphere Packaging (MAP) shows similar results



where the modification behaves like a gas barrier, which slows down the respiration rate by reducing oxygen uptake. (Arowora *et al.*, 2013). Aloe gel-treated nectarines showed similar results (Ahmed *et al.*, 2009; Athmaselvi *et al.*, 2013). It has been found that quality loss is influenced by decreased amounts of acidity (Patanè *et al.*, 2019).

Vitamin C

There was an increase in the ascorbic acid or vitamin C content of treated and untreated tomato, which peaked after 7 days and declined afterward (Figure 2-e). AV+AA+LA coated tomato showed a maximum amount of ascorbic acid and there was no significant difference between AV alone and AV+AA+LA coatings. With maturity, ascorbic acid content increased in tomato but once it reached the maximum ripe stage, concentration declined. A spontaneous process, namely, auto-oxidation occurs when ascorbic acid and oxygen combine, which is a probable reason for the loss in vitamin C (Sogvar *et al.*, 2016). The coating treatment slows down ascorbic acid increment, indicating that the coating layer reduced but did not stop the production of vitamin C. The effective retention of ascorbic acid levels is due to the lower level of gas permeability that retards the physiochemical processes during storage. A similar kind of increase and gradual decrease after maximum value were reported by other studies (Ali *et al.*, 2010; Athmaselvi *et al.*, 2013).

Total Phenolic Content and Antioxidant Activity

Figure 2-f shows the changes in the phenolic content of tomato during storage. The contents of the TP of tomato fruits in different maturity stages studied are within the range observed by others (Odriozola-Serrano *et al.*, 2008; Valdivia-Nájjar *et al.*, 2018). The mature red stage of

tomato showed the maximum polyphenols content; however, the lowest polyphenols content was observed in the mature green phase of tomato. Total phenolic content showed a significant reduction in the over-ripening stage. The increase in physiological activities due to ripening results in an increase in TPC. Similar results were observed in other studies, indicating that the content of total phenols decreases after the maturity stage of tomato fruits (Odriozola-Serrano *et al.*, 2008). However, coated tomato maintained lower values during storage and delayed ripening (Mirdehghan and Valero, 2017). One of the significant biological properties of tomato is the antioxidant capacity of phenols and lycopene. Therefore, maintaining the natural balance of these compounds during storage is very crucial. Results suggest that AV+AA+LA treated tomato showed the lowest amount of TP content.

There was a decrease in antioxidant capacity in all the samples, either treated or untreated (Figure 2-g). The antioxidant capacity of aloe extract was reported in many studies. Different studies confirm that *Aloe vera* gel shows antioxidant capacity because of antioxidant polyphenols, indoles, and alkaloids presence, as confirmed by different analyses (Nejatzadeh-Barandozi, 2013). It is effective in delaying browning, dehydration, and maintains the visual quality of berry without causing any harmful effect on other sensory attributes (Mirdehghan and Valero, 2017). *Aloe vera* may increase its free radical scavenging capacity to resist tissue damage. Antioxidant activity decreases because of senescence at the time of storage. Decreases in antioxidant activity of the samples may be influenced by the capability of retaining fruit quality characteristics by suppressing enzyme activity that destroys antioxidant components. Vitamin C and phenolic compounds are antioxidant compounds that impart antioxidant activity (Tulipani *et al.*, 2008; Sogvar *et al.*, 2016). The delayed ripening process during storage due to treatment of *Aloe vera* edible coating was

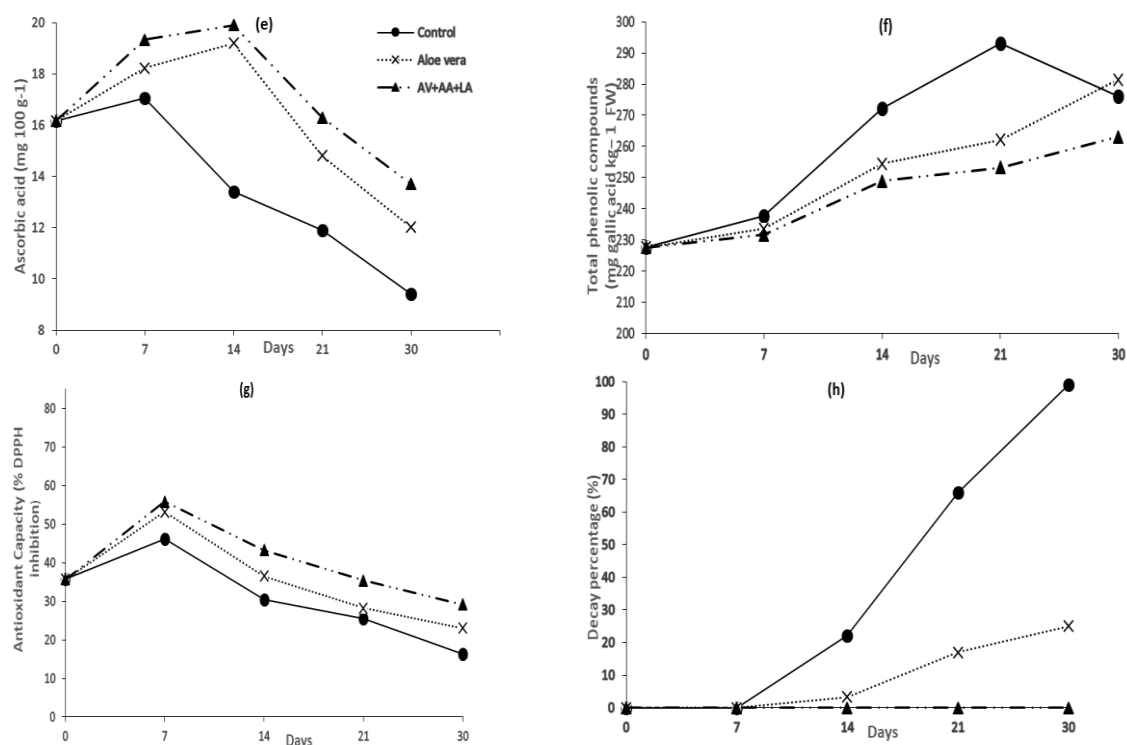


Figure 2. Effect of vitamin C content (mg per 100 g fresh weight) (e), phenolic concentration (Gallic acid in mg per kg fresh weight) (f), antioxidant capacity (% DPPH inhibition) (g), decay percentage(h) in treated or untreated tomato samples during 30 d storage period.

parallel to the previous studies for fruits including strawberry, papaya, nectarine, etc. (Martínez-Romero *et al.*, 2006; Ahmed *et al.*, 2009).

Decay Percentage

The treated and untreated samples showed no sign of decay until day 7, as presented in Figure 2-h. After that, there was a significant reduction in decay in AV+AA+LA treated tomato compared to the other samples, and after 30 days storage, AV+AA+LA treated samples remained free of significant decay. After 21 days of storage, 66% of the control samples showed considerable amount of spoilage. Treated samples decreased decay percentage, perhaps by delaying senescence. Similar results were found in the case of gum Arabic treatment on tomato (Ali *et al.*, 2010). The visual evaluation confirmed that the uncoated tomatoes spoiled extensively

after 21 days of storage (Figure 3). The coating solution of *A. vera* with or without LA+AA appears to have inhibited the ripening when compared with uncoated tomato samples. Figure 3 shows three batches of tomato samples (coated, AV, and AV+LA+AA).

This inhibition in ripening may be due to the effect of the coating layer of *Aloe vera* and AV+LA+AA on the surface. Less surface color change was observed in AV+AA+LA treated samples. In other studies, *Aloe vera* has been reported to have an antifungal effect, which is important for the reduced damage of tomato (Vieira *et al.*, 2016).

CONCLUSIONS

Among all the studies that have been conducted with *Aloe vera*, in this study, for the first time, *Aloe vera* was used in



Figure 3. The gradual change of tomato throughout the storage time at 25-29°C and 82-84% RH over 30 days storage time.

combination with AA+LA in tomato. The results suggested that tomato samples coated with AV+AA+LA retarded postharvest ripening and maintained sample quality attributes most efficiently during storage at 25°C up to 30th day as compared to the untreated control tomato that reached its maximum maturity in 14 days. This study indicated that AV with AA application could be used as a biochemical means for maintaining tomato quality and increasing its shelf life. Additional studies need to be conducted to understand the gaseous exchange of AV+LA+AA coating layer and develop new formulations to apply to different climacteric fruit and vegetables at low temperatures. Further research is needed to understand how coating influences microbial growth and thus affects the ripening process. Addition of *A. vera* with ascorbic acid in the edible coating as bio preservative, which contains antifungal and antioxidant compounds, provides a novel means to enhance safety and increase the postharvest storage life of tomato. It also ensures health and environmental protection

by preventing the use of artificial harmful chemical preservative compounds in various agricultural products.

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تأثیر پوشش خوراکی اسکورییک اسید و لاکتیک اسید بر پایه آلوئه ورا روی کیفیت و ماندگاری گوجه فرنگی

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چکیده

هدف از انجام این پژوهش ارزیابی تأثیر پوشش خوراکی اسکورییک اسید و لاکتیک اسید بر پایه آلوئه ورا (AV) روی ماندگاری و کیفیت گوجه فرنگی بعد از برداشت محصول بود. چندین پوشش مبتنی بر مواد طبیعی مختلف مانند صمغ عربی، carnauba، روغن معدنی، و غیره منجر به افزایش ماندگاری و نگهداری بهتر کیفیت بعد از برداشت شده اند. در این پژوهش، دو پوشش خوراکی از ژل آلوئه ورا و طبیعی (10٪) همراه با اسکورییک اسید (1AA٪) و لاکتیک اسید (1LA٪) به عنوان پوشش های خوراکی به گوجه فرنگی های رسیده، که در حرارت اطاق (25-29 درجه سانتی گراد) و نم نسبی (RH) 82-84٪ به مدت 30 روز انبار شده بود افزوده شد. سپس، مقدار تلفات وزن، اسیدیته کل قابل تیتراژ (TA)، محتوای جامدات محلول (SSC)، محتوای اسکورییک اسید، اسیدیته، محتوای فنول کل، فعالیت آنتی اکسیدانی کل، و درصد پوسیدگی در روزهای 0، 7، 14، 21، و 30 اندازه گیری شد. گوجه فرنگی هایی که پوشش دار شده بود در مقایسه با آنهایی که تیمار نشده بود تاخیر معناداری ($P \leq 0.05$) را در تلفات وزن نشان داد و مقدار بیشتری SSC، ویتامین C، و اسیدیته قابل تیتراژ داشت. در میان دو پوشش آزمون شده، موثرترین پوشش برای تاخیر در رسیدن میوه و نگهداری از تلفات بعد از برداشت، پوشش با 1AA+1LA٪ AV+ بود. نتایج به دست آمده در این بررسی تأکید دارد که می توان از AV و پوشش های خوراکی AA+LA به عنوان گزینه ای موثر برای حفظ و نگهداری گوجه فرنگی، تاخیر در فرایند رسیدن میوه، و طولانی کردن ماندگاری استفاده کرد.