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## Enhancing tomato shelf-life and preserving antioxidant properties with salicylic acid and aloe vera coating

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### Abstract

The purpose of this study was to examine how tomato fruit's antioxidant properties and quality were affected by edible coating and salicylic acid dip. Fresh tomatoes were coated with aloe vera (AL) gel and salicylic acid (SA) and kept for 28 days at about 4°C and 85-90% relative humidity. Following the application of coating materials, tomato fruits were assessed for various quality parameters at an interval of seven days. The findings demonstrated that combining salicylic acid with an aloe vera-based coating is a successful and efficient way to extend tomato shelf-life and maintain its antioxidant property throughout the 28 day storage period at 4°C. Out of all the treatments, 20% aloe vera + 2% mmol salicylic acid (T4) produced the best coating combination for maintaining the quality. This combination resulted in a delayed weight loss of 3.78 per cent, with no decay. The results also indicated that fruits coated with 2 mmol salicylic acid and 20% aloe vera gel had greater levels of lycopene retention (5.98 mg /100 g) and DPPH scavenging activity (42.44%). At 28 days of cold storage, there was high firmness retention (1.95N) when treated with 2 mmol salicylic acid and 20% aloe vera gel coating. Fruit quality and shelf-life can be improved through the industrial application of this innovative edible coating method.

### 1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most widely cultivated and consumed fruits in the world, known for its rich flavor, versatility, and nutritional value. Originating from the Andean region of South America, it has become a staple in various cuisines, from salads to sauces, and is used in both fresh and processed forms. Tomatoes are an excellent source of vitamins, especially vitamin C, and antioxidants such as lycopene, which have been linked to numerous health benefits, including reducing the risk of chronic diseases.

Tomato is a significant source of polyphenolic compounds, which are essential for their health-promoting qualities. The most common polyphenols in tomatoes include rutin, quercetin, naringenin, caffeic acid, ferulic acid, and chlorogenic acid. Depending on variables like tomato cultivar, maturity, and development environment, the amount and makeup of these polyphenols might vary significantly. For instance, research has shown that the levels of chlorogenic acid can range from 1.4 to 3.3 mg per 100 g of fresh weight, while quercetin levels may vary from 0.7 to 4.4 mg per 100 g (Martí *et al.*, 2016).

The primary antioxidant in tomatoes, lycopene, protects cells from oxidative damage and has been linked to a reduced risk of certain cancers, including prostate and colorectal cancers, as well as cardiovascular diseases (Saini *et al.*, 2020). Additionally, tomatoes provide both soluble and insoluble fiber, aiding digestion and promoting bowel health while being low in calories, approximately 18 calories per 100 g of tomato. Consuming tomatoes regularly lowers blood pressure and cholesterol, which benefits heart health.

Dipping tomato pieces in various chemical solutions has been found to improve their structural integrity by forming cross-links between pectin molecules, thus slowing down textural degradation (Dodgson *et al.*, 2023). This treatment can be particularly beneficial for cut or sliced tomatoes, extending their shelf-life from a day to up to two weeks when stored properly. Additionally, hot water treatments have been employed to reduce chilling injuries and enhance pathogen resistance in tomatoes (Bunkar *et al.*, 2020). By exposing tomatoes to temperatures between 37°C and 42°C before cold storage, researchers have observed slowed ripening processes and improved quality retention (Arah *et al.*, 2016). Overall, these post-harvest dipping treatments, whether through chemical disinfectants like sodium hypochlorite, calcium solutions for texture improvement, or heat treatments, significantly contribute to prolonging the shelf-life of tomatoes, making them more marketable and reducing waste in the supply chain. Gel coatings are an essential innovation in the post-harvest preservation of tomatoes, offering numerous benefits that enhance their shelf-life, quality, and sustainability. These coatings, often made from natural or synthetic materials, are applied to the surface of tomatoes after harvesting to create a protective barrier

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that slows down the degradation process. One of the primary advantages of gel coatings is their ability to extend the shelf-life of tomatoes by reducing moisture loss (Duguma, 2022). Tomatoes are highly perishable, and their rapid dehydration leads to shriveling and spoilage. The gel coating acts as a barrier, helping to retain moisture and preserve the fruit's texture and firmness for a longer period. Additionally, gel coatings slow down the ripening process by limiting exposure to oxygen, thereby reducing the production of ethylene, a hormone that accelerates ripening. This slower ripening extends the tomato's freshness and makes it more suitable for transportation and retail distribution. In terms of physical protection, tomatoes are soft and easily damaged during handling, packaging, and transport. Gel coatings provide an extra layer of defense, minimizing bruising, scuffing, and other mechanical damage that could otherwise affect the fruit quality. This added protection helps maintain the tomatoes' appearance and integrity, ensuring that they reach consumers in the best possible condition (Borah *et al.*, 2016). Furthermore, gel coatings help reduce microbial spoilage by acting as a barrier to bacteria, fungi, and other pathogens that commonly cause fruit rot.

Research on the effects of salicylic acid (SA) and aloe vera gel coatings on the post-harvest life of tomatoes under cold storage is essential for reducing post-harvest losses and ensuring the quality of fruit. Tomatoes are highly perishable, and post-harvest losses significantly impact the agricultural economy and food availability. Salicylic acid, known for its ability to induce stress tolerance, delay senescence, and regulate ethylene production, helps preserve fruit quality during storage (Baninaiem *et al.*, 2016). Aloe vera gel enhances salicylic acid protective properties by functioning as a natural barrier that inhibits moisture loss and microbial growth (Firdous *et al.*, 2020). When combined, they offer a sustainable agricultural option and healthier consumer choices by offering an environmentally friendly substitute for synthetic chemicals.

This research is particularly relevant in optimizing edible coatings, as it explores how natural coatings interact with low temperatures to maintain tomatoes' firmness, color, and nutritional content. By determining the optimal concentrations of salicylic acid and aloe vera gel, the study offers practical solutions for extending shelf-life, reducing post-harvest losses, and improving transport durability. Additionally, the findings have potential applications for other perishable crops, further amplifying their economic and environmental benefits. In conclusion, this study addresses critical challenges in post-harvest management while promoting natural and sustainable solutions for preserving fresh produce.

## 2. Materials and Methods

### 2.1 Raw materials procurement

Ripe-stage tomato fruits *L. esculentum*, homogenous in size, red in color, and free from visible defects, were sourced from the Division of Olericulture, SKUAST-K Shalimar. The tomatoes were manually rinsed with tap water to eliminate contaminants and soil and then positioned on a plastic mesh to facilitate drainage of surplus water. Aloe vera plants were collected from the local market of Srinagar, Kashmir. Analytical-grade chemicals were supplied by regional supplier (B.M Scientific Ltd.). The tomato plant is authenticated by Dr. Nazeer Ahmad, Ex. Head of the Division, Division of Vegetable Science, SKUAST-K. The Herbarium No. is SH-FMS-IX SH-T-11.

### 2.2 Preparation of aloe vera gel

After separating the aloe vera gel matrices from the leaf's external layer, the colorless aqueous parenchyma was homogenized to form the undiluted aloe vera gel. To get rid of the fibers, the gel was diluted with 10% and 20% distilled water and then screened. For 45 min, the gel matrix was pasteurized at 70°C and then cooled to around 26°C. (Paul *et al.*, 2024).

### 2.3 Preparation of salicylic acid solution

The salicylic acid concentration consisted of 1.0 m mol SA/l and 2.0 m mol SA/l. The necessary amount of SA was dissolved in distilled water while being stirred for 30 min to prepare the solution. The mixture was then kept at room temperature.

### 2.4 Development of coating material

A required quantity of salicylic acid and aloe vera gel was mixed in a beaker. A vortex mixture was used to adequately mix it until it reached approximately 26, which produced the salicylic acid aloe vera gel coating solution.

### 2.5 Application of coating on tomato surface

Five different treatments were used in the present investigation, designated as control: T0 (no treatment), T1 (tomato coated with 10% aloe vera gel and 1 m mol SA), T2 (tomato coated in 20% aloe vera gel and 1 m mol SA), T3 (tomato coated with 10% aloe vera gel and 2 m mol SA), and T4 (tomato coated in 20% aloe vera gel and 2 m mol SA). For 15 mins, the fresh fruits were immersed in the mixtures at room temperature. The tomatoes developed a transparent covering on their outer skin. They were left to dry at about 26°C to create a thin layer.

### 2.6 Analytical methods

Tomato, after application of coating, was examined for various quality parameters for the period of 28 days at an interval of 7 days while they were kept in storage at 4°C and 85-90% relative humidity. Days 0, 7, 14, 21, and 28 were used to test physicochemical parameters.

#### 3.6.1 Firmness (N)

A texture analyzer (TA-HD Plus) was used to determine the texture (Islam *et al.*, 2019). The test conditions included a cylindrical probe, a 2 mm plunger tip, a 1.5 mm/s test speed, and a 5 mm penetration depth. The mean value was recorded after five evaluations were made in five arbitrarily selected spots.

#### 3.6.2 Physiological weight loss (%)

To calculate the physiological loss in weight (PLW) for each treatment, 500 g of fruits were individually packed. The initial weight of these fruits was measured immediately after the precooling treatment. Subsequently, the fruits were weighed at each analysis stage. PLW was then expressed as a percentage using the following equation:

$$PLW (\%) = \frac{\text{Original weight} - \text{Subsequent weight at analysis}}{\text{Original weight}} \times 100$$

#### 3.6.3 Decay (%)

The decay percentage was computed at the end of each storage interval, considering the number of fruits that had either spoiled or rotted during the storage period, as indicated by the following equation:

$$\text{Decay (\%)} = \frac{\text{No. of spoiled or rotten fruits}}{\text{Total No. of fruits}} \times 100$$

#### 2.6.4 Total soluble solids ("Brix)

The assessment of total soluble solids was carried out using a hand refractometer (model Atago N, Japan) with a range of 0-32%, and the obtained values in percentage were adjusted at 20°C, as per the method outlined by Rangana (1997). For the test, the fruits were divided into three replicates, each comprising 10 fruits, and underwent juice extraction using an Omni mixer, followed by filtration through a muslin cloth. Two to three drops of the filtered juice were applied to the refractometer lens for the measurement of total soluble solids (TSS).

#### 2.6.5 Ascorbic acid (mg/100 g)

Ascorbic acid was measured using the method outlined by Ranganna (1986), involving the 2,6-dichlorophenol indophenol dye. The dye factor was established by titrating a 5 ml mixture of standard ascorbic acid and 5 ml of 3% metaphosphoric acid with the 2,6-dichlorophenol indophenol dye until a pink color appeared, with the volume of dye consumed being noted. The ascorbic acid content was expressed in mg per 100 g and determined using the following formula:

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Titre} \times \text{Dye equivalent} \times \text{Dilution}}{\text{Weight or Volume of Sample} \times \text{Aliquot of extract taken for estimation}}$$

#### 2.6.6 Lycopene (mg/100 g)

The concentration of lycopene in tomato powder was evaluated utilizing approaches mentioned in research conducted by Srivastava and Kumar (2004). The extraction process started with 5-10 g of the analyte, using acetone as the extraction solvent. The acetone extract was subsequently poured into an isolated decanter with 10-15 ml of ligroin and a 5% sodium sulfate solution to remove excess moisture. The mixture was repetitively extracted until it was clear. The layer of pet ether containing the lycopene, was collected, and volume was adjusted to 50 ml. Furthermore, the lycopene concentration, along with the absorbance, was assessed at 472 nm with a UV-Vis spectrophotometer.

#### 2.6.7 % DPPH (2, 2-diphenyl-1-picrylhydrazyl) inhibition assay

The Brand-Williams *et al.* (1995) method for the DPPH assay was applied with minor modifications. The stock solution was made by mixing 24 mg of DPPH with 100 ml of methanol and storing it at 20°C until it was needed. The working solution, which had an absorbance of 515 nm, was made by mixing 10 ml of stock solution with 45 ml of methanol using a spectrophotometer. After mixing 150 micro litre of fruit extracts with 2850 micro litre of the DPPH solution, the mixture was allowed to react in the dark for a whole day. The absorbance was then measured at 515 nm. The antioxidant activity was expressed as the scavenging percentage using the following formula.

$$\% \text{ Inhibition of DPPH} = \frac{\text{Abs control} - \text{Abs sample}}{\text{Abs control}} \times 100$$

where, Abs = Absorbance

#### 2.6.8 Microbial count (log cfu/g)

The overall microbial count was determined using the standard serial dilution plate count technique with Nutrient Agar and Potato Dextrose Agar, following the procedure described by Martin (1950). For this analysis, 10 g of the sample was mixed with 90 ml of water to create a suspension. After stirring for 5 min, aliquots of the suspension were serially diluted and used for plate counting. One milliliter of each appropriate dilution was transferred to sterile plates, and molten agar media, cooled to 45°C, was poured onto the plates. The plates were gently swirled to evenly distribute the inoculum before the medium solidified. After incubating the plates at 32°C for 3-5 days, the colonies were counted, and the results were reported as log cfu/g, representing the logarithm of the number of colony-forming units per g.

### 3. Results

#### 3.1 Firmness (N)

The study (Figure 1) revealed that the firmness of tomatoes stored in cold store conditions gradually decreased across all treatments over time, with notable differences between the control ( $T_0$ ), the aloe vera gel coated and salicylic acid coated treatments. At the beginning of storage (Day 0), there was no significant difference ( $p \leq 0.05$ ) in firmness among the treatments, with values ranging from  $3.80 \pm 0.17$  N ( $T_2$ ) to  $3.99 \pm 0.33$  N ( $T_4$ ). However, as storage progressed, clear trends began to emerge. By Day 14,  $T_3$  ( $2.92 \pm 0.21$  N) and  $T_4$  ( $2.90 \pm 0.40$  N) treatments exhibited significantly ( $p \leq 0.05$ ) higher firmness compared to the control ( $2.65 \pm 0.15$  N). However,  $T_2$  and  $T_1$  treatments maintained intermediate firmness levels. The differences became even more pronounced by Day 21, when  $T_3$  ( $2.61 \pm 0.40$  N) and  $T_4$  ( $2.62 \pm 0.42$  N) treatments showed significantly ( $p \leq 0.05$ ) higher firmness than  $T_0$  ( $2.10 \pm 0.25$  N), with  $T_2$  ( $2.52 \pm 0.15$  N) also outperforming the control. By the end of storage (Day 28),  $T_4$  treatment had the highest firmness ( $1.95 \pm 0.33$  N), followed by  $T_2$  ( $1.75 \pm 0.21$  N) and  $T_3$  ( $1.70 \pm 0.40$  N), while control ( $1.48 \pm 0.46$  N) had the lowest firmness. Overall, the trend throughout the storage period indicated that salicylic acid and aloe vera gel-based coatings, especially  $T_4$ , effectively slowed down the decrease in firmness of tomatoes compared to the control. These findings highlight the preventive function of coatings made of salicylic acid and aloe vera gel in maintaining tomato firmness during cold storage. Among the treatments,  $T_4$  consistently showed the best performance, followed by  $T_2$  and  $T_3$ , respectively. In contrast, the control ( $T_0$ ) had the lowest firmness retention, highlighting its lack of protective effect.

#### 3.2 Physiological weight loss (%)

The study assessed how an aloe vera gel and salicylic acid-based coating affects the physiological loss in weight (plw) of tomatoes stored under cold storage conditions for 28 days. The findings (Figure 2) revealed that the salicylic acid and aloe vera-based coating significantly ( $p \leq 0.05$ ) decreased PLW when compared to the control ( $T_0$ ). On day 7, PLW varied from 1.18% in  $T_4$  to 1.99% in  $T_0$ , with  $T_4$  showing the least physiological weight loss. By day 14, PLW in  $T_0$  rose to 4.24%, while the coated treatments ( $T_1$ - $T_4$ ) displayed notably lower values, ranging from 3.24% ( $T_1$ ) to 3.56% ( $T_2$ ). After 21 days,  $T_4$  continued to have the lowest PLW at 4.68%, followed by  $T_2$  (8.50%) and  $T_3$  (9.54%), while  $T_0$  had the highest loss at 9.70%. At the end of the storage period (28 days),  $T_0$  showed the

highest PLW at 16.05%, whereas T<sub>4</sub> achieved the best results with the lowest PLW of 7.35%. The average PLW across all treatments steadily increased from day 7 (1.30%) to day 28 (11.57%). These findings suggest that aloe vera gel and salicylic acid-based coating effectively minimize weight loss in tomatoes by reducing moisture

loss during storage. Among the treatments, T<sub>4</sub> consistently exhibited the lowest PLW throughout the storage duration, emphasizing its effectiveness in preserving the quality and freshness of tomatoes using aloe vera gel and salicylic acid-based based coating under cold storage conditions.

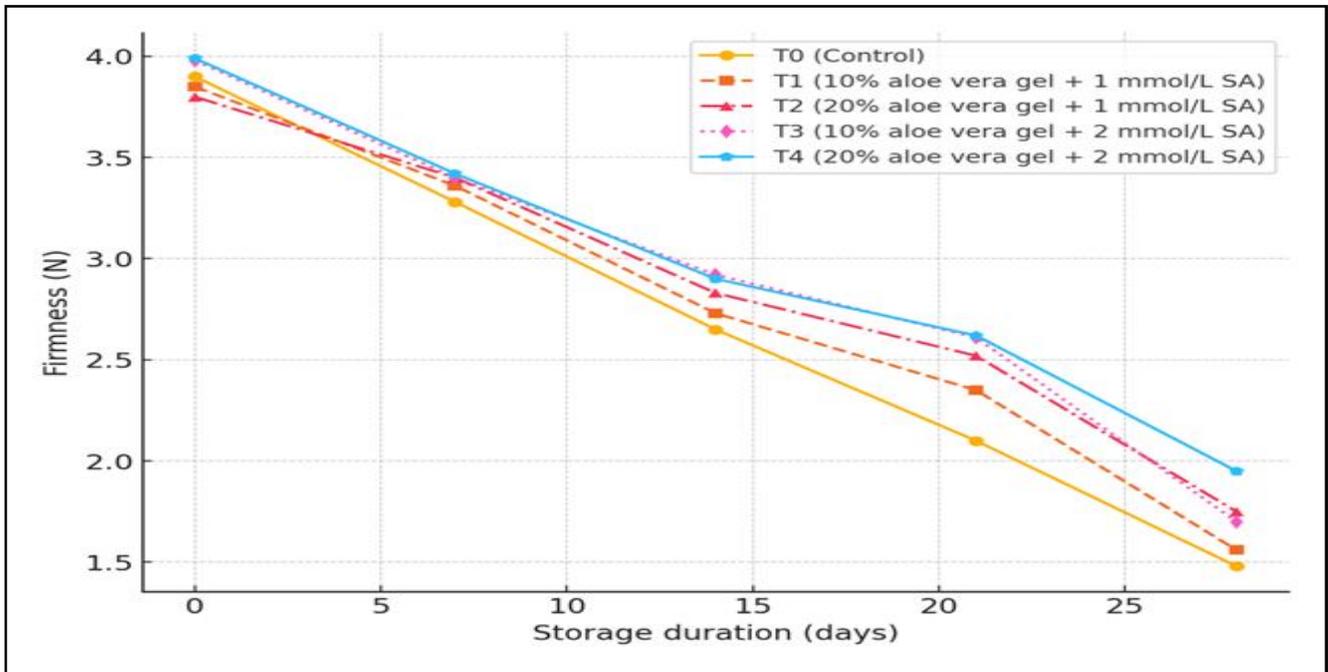


Figure 1: Effect of aloe vera gel and salicylic acid-based coatings on firmness (N) of tomato under cold storage conditions.

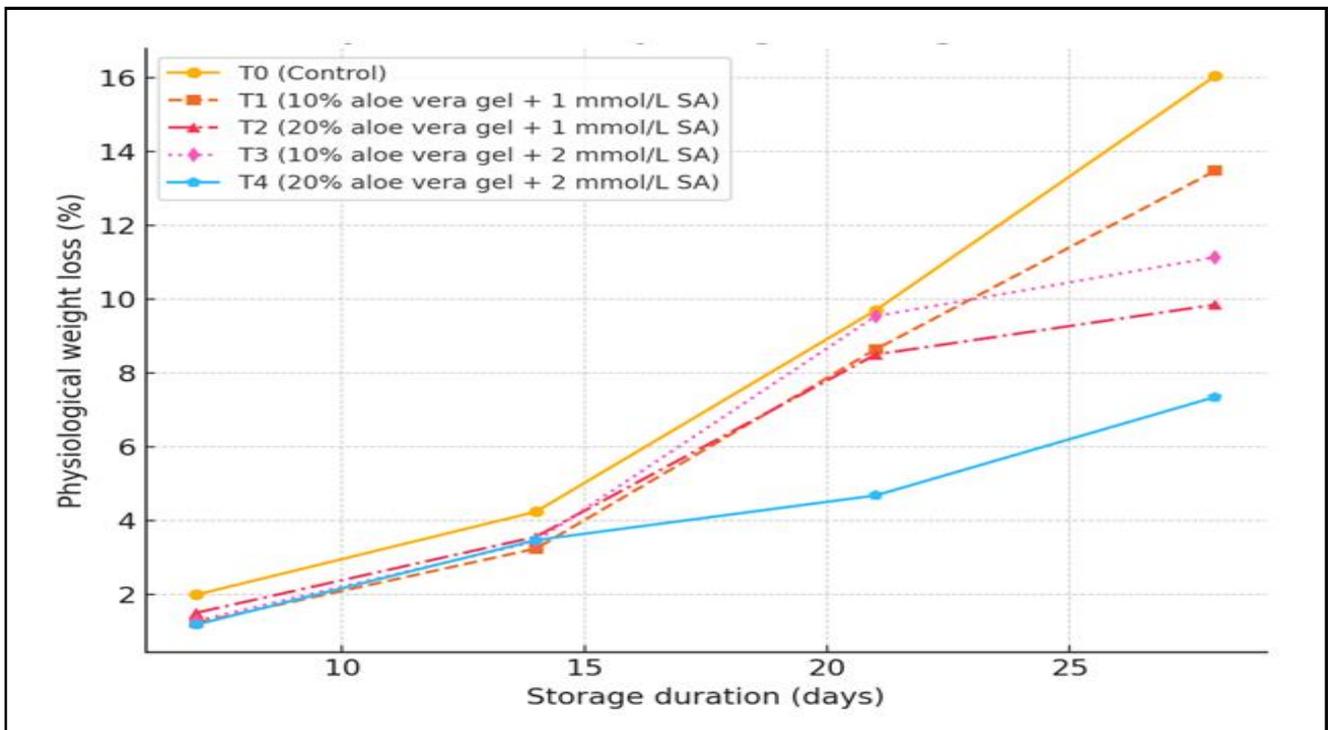


Figure 2: Effect of aloe vera gel and salicylic acid-based coatings on physiological weight loss (%) of tomatoes under cold storage conditions.

### 3.3 Decay (%)

The study explored how an aloe vera gel and salicylic acid-based coating affects the decay rate of tomatoes stored under cold conditions for 28 days. The findings (Table 1) revealed that untreated tomatoes ( $T_0$ ) experienced no decay (ND) until day 21, when decay was recorded at 10.47%, increasing to 20.51% by day 28. In contrast, tomatoes treated with aloe vera gel and salicylic acid showed a notable decrease in decay. Treatment  $T_1$  had a decay percentage of 8.72% on day 21, which increased to 18.33% by day 28. Treatment  $T_2$  recorded lower decay rates, with 5.57% on day 21 and 10.23% by day 28. Treatment  $T_3$  observed the best results, showing a decay percentage

of 3.12% on day 21 and 5.33% by day 28. Remarkably, treatment  $T_4$  exhibited no decay throughout the entire storage period. The average decay percentage for  $T_0$ ,  $T_1$ ,  $T_2$ , and  $T_3$  over the storage duration was 15.49%, 13.53%, 7.90%, and 4.23%, respectively, while  $T_4$  maintained an average decay percentage of zero. Overall, the aloe vera gel and salicylic acid-based coating significantly minimized decay in tomatoes during cold storage, with  $T_4$  proving to be the most effective treatment, followed by  $T_3$ ,  $T_2$ , and  $T_1$ , in comparison to the control ( $T_0$ ). This indicates that aloe vera gel and salicylic acid is a promising natural preservative for prolonging the shelf-life and preserving the quality of tomatoes during storage.

**Table 1: Effect of aloe vera gel and salicylic acid-based coatings on decay (%) of tomato fruit under cold storage conditions**

Treatments	0 Day	7 Days	14 Days	21 Days	28 Days
$T_0$	ND	ND	ND	10.47 ± 0.68 <sup>d,1</sup>	20.51 ± 0.40 <sup>d,2</sup>
$T_1$	ND	ND	ND	8.72 ± 0.50 <sup>c,1</sup>	18.33 ± 0.33 <sup>c,2</sup>
$T_2$	ND	ND	ND	5.57 ± 0.45 <sup>b,1</sup>	10.23 ± 0.25 <sup>b,2</sup>
$T_3$	ND	ND	ND	3.12 ± 0.15 <sup>a,1</sup>	5.33 ± 0.21 <sup>a,2</sup>
$T_4$	ND	ND	ND	ND	ND

$T_0$ = Control,  $T_1$ = 10% aloe vera gel and 1 mmol SA,  $T_2$ = 20% aloe vera gel and 1 mmol SA,  $T_3$ = 10% aloe vera gel and 2 mmol SA,  $T_4$ = 20% aloe vera gel and 2 mmol SA; ND = No Decay; Value are mean ± SD

Values within treatments in a column not sharing a common superscript lowercase letter (a/e) are significantly ( $p \leq 0.05$ ) different.

Values within storage periods in a row not sharing a common superscript numerical (1/5) are significantly ( $p \leq 0.05$ ) different.

### 3.4 Total soluble solids (°Brix)

The study investigated how aloe vera gel and salicylic acid-based coating affect the total soluble solids (TSS) (°Brix) of tomatoes stored under cold storage conditions for 28 days (Table 2). Throughout the storage period, the TSS content gradually decreased, with differences observed among the treatments. On day 0, TSS levels were comparable across all treatments, ranging from 4.82°Brix ( $T_4$ ) to 4.88°Brix ( $T_2$ ). By day 7, TSS values slightly increased in most treatments, with  $T_1$  (4.95°Brix) and  $T_2$  (4.92°Brix) showing higher levels than  $T_0$  (4.89°Brix). After 14 days, TSS decreased, with  $T_4$  (4.23°Brix) and

$T_3$  (4.24°Brix) recording the lowest values, while  $T_0$  observed a TSS value of 4.37°Brix. On day 21,  $T_4$  demonstrated better TSS retention (4.63°Brix) compared to the other treatments, with  $T_3$  and  $T_2$  showing lower levels at 3.88°Brix and 4.00°Brix, respectively. By the end of the storage period (28 days), TSS was highest in  $T_4$  (4.50°Brix) and lowest in  $T_3$  (3.54°Brix). These findings indicate that aloe vera gel-based coating positively affected the TSS content of tomatoes, with  $T_4$  maintaining relatively stable levels over time, suggesting its potential to maintain tomato quality while they are being kept in cold storage.

**Table 2: Effect of aloe vera gel and salicylic acid-based coatings on TSS (°Brix) of tomato under cold storage conditions**

Treatments	Day 0	Day 7	Day 14	Day 21	Day 28
$T_0$	4.84 ± 0.45 <sup>a,1</sup>	4.89 ± 0.27 <sup>c,2</sup>	4.37 ± 0.21 <sup>c,4</sup>	4.17 ± 0.33 <sup>b,3</sup>	3.88 ± 0.27 <sup>b,2</sup>
$T_1$	4.87 ± 0.36 <sup>a,1</sup>	4.95 ± 0.21 <sup>b,2</sup>	4.43 ± 0.27 <sup>b,4</sup>	4.20 ± 0.25 <sup>a,3</sup>	3.85 ± 0.36 <sup>b,3</sup>
$T_2$	4.88 ± 0.37 <sup>a,1</sup>	4.92 ± 0.15 <sup>a,1</sup>	4.50 ± 0.41 <sup>b,3</sup>	4.00 ± 0.22 <sup>a,2</sup>	4.90 ± 0.72 <sup>b,2</sup>
$T_3$	4.84 ± 0.40 <sup>a,1</sup>	4.90 ± 0.40 <sup>a,1</sup>	4.24 ± 0.40 <sup>a,3</sup>	3.88 ± 0.17 <sup>a,2</sup>	3.54 ± 0.40 <sup>a,1</sup>
$T_4$	4.82 ± 0.13 <sup>a,1</sup>	4.86 ± 0.25 <sup>a,1</sup>	4.23 ± 0.33 <sup>a,3</sup>	4.63 ± 0.15 <sup>a,2</sup>	4.50 ± 0.25 <sup>a,1</sup>

$T_0$ = Control,  $T_1$ = 10% aloe vera gel and 1 mmol SA,  $T_2$ = 20% aloe vera gel and 1 mmol SA,  $T_3$ = 10% aloe vera gel and 2 mmol SA,  $T_4$ = 20% aloe vera gel and 2 mmol SA; Values are mean ± SD

Values within treatments in a column not sharing a common superscript lowercase letter (a/e) are significantly ( $p \leq 0.05$ ) different.

Values within storage periods in a row not sharing a common superscript numerical (1/5) are significantly ( $p \leq 0.05$ ) different.

### 3.5 Ascorbic acid (mg/100 g)

The effect of aloe vera gel and salicylic acid-based coating on the ascorbic acid content (mg/100 g) of tomatoes during cold storage depicted (Table 3) that ascorbic acid levels were comparable across treatments, ranging from 28.11 mg/100 g ( $T_2$ ) to 29.68 mg/100 g ( $T_4$ ) on day 0. Throughout the storage period, ascorbic acid content declined in all treatments. After 7 days,  $T_4$  exhibited the highest ascorbic acid content at 21.52 mg/100 g, closely followed by  $T_3$  at 21.10 mg/100 g, while  $T_0$  decreased significantly ( $p \leq 0.05$ ) to 18.56 mg/100 g. By day 14,  $T_4$  still held the highest ascorbic acid content at 19.56 mg/100 g, with  $T_3$  at 19.13 mg/100 g and  $T_2$  at 18.15 mg/100 g, whereas  $T_0$  decreased further to 14.53 mg/100 g. On day 21,  $T_4$

continued to lead with 12.92 mg/100 g, while  $T_3$  and  $T_2$  maintained relatively higher levels at 12.57 mg/100 g and 12.51 mg/100 g, compared to  $T_0$ , which was at 10.49 mg/100 g, respectively. By the end of the storage period (28 days),  $T_4$  recorded the highest ascorbic acid content at 9.62 mg/100 g, followed by  $T_3$  at 9.35 mg/100 g and  $T_2$  at 9.15 mg/100 g, while  $T_0$  had the lowest ascorbic acid content at 8.42 mg/100 g. The average ascorbic acid content over the storage period was highest in  $T_4$  at 18.67 mg/100 g, followed by  $T_3$  at 18.35 mg/100 g and  $T_2$  at 17.63 mg/100 g.  $T_1$  (16.77 mg/100 g) and  $T_0$  (16.28 mg/100 g) had slightly lower average values. These findings indicate that the aloe vera gel and salicylic acid-based coating, especially  $T_4$ , was effective in preserving the ascorbic acid content in tomatoes during cold storage, thus helping to maintain the nutritional quality of fruit.

**Table 3: Effect of aloe vera gel and salicylic acid-based coatings on ascorbic acid content (mg/100 g) of tomato during cold storage**

Treatments	Day 0	Day 7	Day 14	Day 21	Day 28
$T_0$	29.42 ± 0.52 <sup>b,5</sup>	18.56 ± 0.49 <sup>a,4</sup>	14.53 ± 0.16 <sup>a,3</sup>	10.49 ± 0.51 <sup>1a,2</sup>	8.42 ± 0.33 <sup>b,1</sup>
$T_1$	29.57 ± 0.62 <sup>b,5</sup>	20.37 ± 0.52 <sup>b,4</sup>	15.27 ± 0.45 <sup>b,3</sup>	10.50 ± 0.40 <sup>a,2</sup>	8.16 ± 0.25 <sup>a,1</sup>
$T_2$	28.11 ± 0.17 <sup>a,5</sup>	20.24 ± 0.20 <sup>b,4</sup>	18.15 ± 0.15 <sup>c,3</sup>	12.51 ± 0.33 <sup>b,2</sup>	9.15 ± 0.17 <sup>c,1</sup>
$T_3$	29.58 ± 0.29 <sup>b,5</sup>	21.10 ± 0.38 <sup>c,4</sup>	19.13 ± 0.22 <sup>d,3</sup>	12.57 ± 0.25 <sup>b,2</sup>	9.35 ± 0.62 <sup>c,1</sup>
$T_4$	29.68 ± 0.18 <sup>c,5</sup>	21.52 ± 0.53 <sup>c,4</sup>	19.56 ± 0.39 <sup>d,3</sup>	12.92 ± 0.1 <sup>c,2</sup>	9.62 ± 0.50 <sup>d,1</sup>

$T_0$ = Control,  $T_1$ = 10% aloe vera gel and 1 mmol SA,  $T_2$ = 20% aloe vera gel and 1 mmol SA,  $T_3$ = 10% aloe vera gel and 2 mmol SA,  $T_4$ = 20% aloe vera gel and 2 mmol SA; Values are mean ± SD

Values within treatments in a column not sharing a common superscript lowercase letter (a/e) are significantly ( $p \leq 0.05$ ) different.

Values within storage periods in a row not sharing a common superscript numerical (1/5) are significantly ( $p \leq 0.05$ ) different.

### 3.6 Lycopene (mg/100 g)

The effect of aloe vera gel and salicylic acid-based coating on the lycopene content of tomato (mg/100 g) over 28 days of cold storage is depicted in Table 4. Lycopene content generally declined over the storage period in all treatments, with coated tomatoes retaining higher lycopene levels compared to the control ( $T_0$ ). On day 0, lycopene content was similar across the treatments, ranging from 8.43 to 8.65 mg/100 g. By day 7,  $T_3$  (7.15 mg/100 g) and  $T_4$  (7.05 mg/100 g) showed higher lycopene content than  $T_0$  (6.71 mg/100 g). After 14 days, lycopene levels decreased further, with  $T_4$  (7.07 mg/100 g)

retaining the highest lycopene content, followed by  $T_3$  (6.72 mg/100 g), while  $T_0$  recorded the lowest value at 6.42 mg/100 g. On day 21,  $T_4$  demonstrated the highest retention of lycopene (6.92 mg/100 g), significantly ( $p \leq 0.05$ ) outperforming  $T_0$  (5.62 mg/100 g). By the end of the storage period (28 days), lycopene content decreased across all treatments, with  $T_4$  maintaining the highest level (5.98 mg/100 g) and  $T_0$  the lowest (4.09 mg/100 g) value of lycopene content. The mean value of lycopene content over the storage period was highest in  $T_4$  (7.09 mg/100 g), followed by  $T_3$  (6.90 mg/100 g) and  $T_2$  (6.70 mg/100 g), while  $T_0$  had the lowest mean value (6.25 mg/100 g).

**Table 4: Effect of aloe vera gel and salicylic acid-based coatings on lycopene content (mg/100 g) of tomato under cold storage conditions**

Treatments	0 Day	7 Days	14 Days	21 Days	28 Days
$T_0$	8.45 ± 0.15 <sup>a,5</sup>	6.71 ± 0.25 <sup>a,4</sup>	6.42 ± 0.15 <sup>a,3</sup>	5.62 ± 0.31 <sup>a,2</sup>	4.09 ± 0.36 <sup>a,1</sup>
$T_1$	8.65 ± 0.31 <sup>a,5</sup>	6.91 ± 0.25 <sup>a,4</sup>	6.58 ± 0.21 <sup>a,3</sup>	6.00 ± 0.15 <sup>b,2</sup>	4.88 ± 0.41 <sup>b,1</sup>
$T_2$	8.44 ± 0.17 <sup>a,5</sup>	6.85 ± 0.33 <sup>a,4</sup>	6.65 ± 0.30 <sup>a,3</sup>	6.39 ± 0.21 <sup>c,2</sup>	5.15 ± 0.46 <sup>c,1</sup>
$T_3$	8.43 ± 0.25 <sup>a,5</sup>	7.15 ± 0.35 <sup>b,4</sup>	6.72 ± 0.45 <sup>b,3</sup>	6.51 ± 0.33 <sup>d,2</sup>	5.68 ± 0.15 <sup>d,1</sup>
$T_4$	8.43 ± 0.15 <sup>a,3</sup>	7.05 ± 0.40 <sup>b,2</sup>	7.07 ± 0.25 <sup>c,2</sup>	6.92 ± 0.50 <sup>e,2</sup>	5.98 ± 0.50 <sup>e,1</sup>

$T_0$ = Control,  $T_1$ = 10% aloe vera gel and 1 mmol SA,  $T_2$ = 20% aloe vera gel and 1 mmol SA,  $T_3$ = 10% aloe vera gel and 2 mmol SA,  $T_4$ = 20% aloe vera gel and 2 mmol SA; Values are mean ± SD

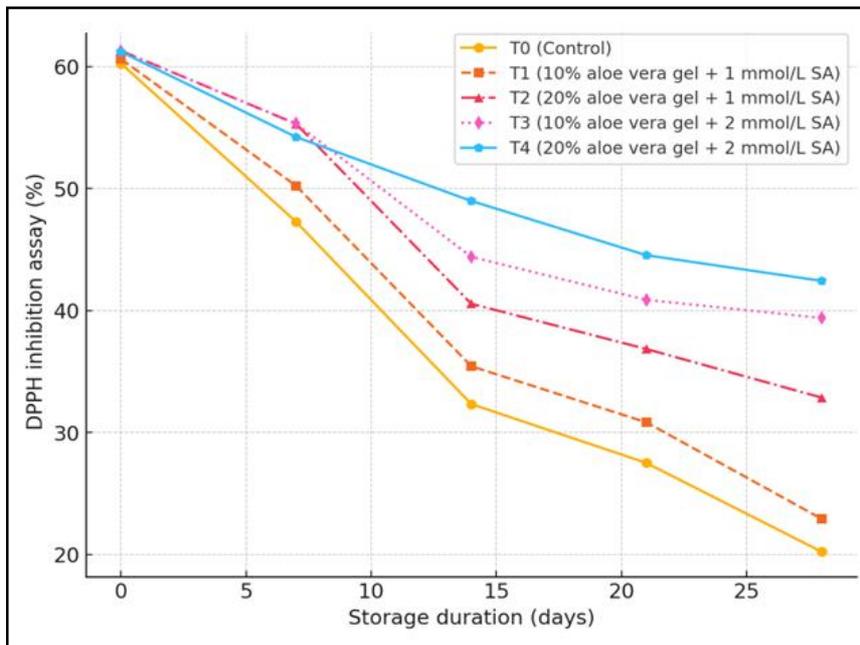
Values within treatments in a column not sharing a common superscript lowercase letter (a/e) are significantly ( $p \leq 0.05$ ) different.

Values within storage periods in a row not sharing a common superscript numerical (1/5) are significantly ( $p \leq 0.05$ ) different.

**3.7 %DPPH inhibition assay**

The study evaluated the effect of aloe vera gel and salicylic acid-based coatings on DPPH scavenging activity (%) of tomatoes stored under cold storage for 28 days as shown in Figure 3. At the 0 days of storage, the DPPH scavenging activity was similar across all treatments, ranging from 60.26% (T<sub>0</sub>) to 61.31% (T<sub>2</sub>). Throughout the storage period, the DPPH scavenging activity decreased in all treatments. On day 7, T<sub>2</sub> (55.31%) and T<sub>3</sub> (55.33%) showed higher scavenging activity compared to the other treatments, while T<sub>0</sub> showed DPPH % of 47.28%. After 14 days, the DPPH activity continued to decline, with T<sub>3</sub> (44.41%) and T<sub>2</sub> (40.56%) retaining

the highest levels, whereas T<sub>0</sub> showed a significant ( $p \leq 0.05$ ) decrease in DPPH activity to 32.34%. By day 21, T<sub>3</sub> (40.88%) and T<sub>4</sub> (44.54%) exhibited the best scavenging activity, while T<sub>0</sub> showed a further decrease to 27.51%. After 28-days of storage, T<sub>3</sub> (39.40%) and T<sub>4</sub> (42.44%) maintained relatively high scavenging activity, in contrast to T<sub>0</sub>, which recorded the lowest value of DPPH activity at 20.23%. These results suggest that aloe vera gel and salicylic acid-based coating effectively helps preserve DPPH scavenging activity in tomatoes during cold storage, with T<sub>3</sub> and T<sub>4</sub> demonstrating the best retention of antioxidant properties, underscoring the potential of aloe vera gel and salicylic acid in maintaining the nutritional quality of tomatoes throughout storage.



**Figure 3:** Effect of aloe vera gel and salicylic acid-based coatings on DPPH inhibition assay (%) of tomato under cold storage conditions.

**Table 5:** Effect of aloe vera gel and salicylic acid-based coatings on microbial load (log cfu/g) of tomato under cold storage conditions

Treatments	Day 0	Day 7	Day 14	Day 21	Day 28
T <sub>0</sub>	1.25 ± 0.31 <sup>a,1</sup>	1.75 ± 0.50 <sup>b,2</sup>	2.25 ± 0.15 <sup>c,3</sup>	2.65 ± 0.21 <sup>b,4</sup>	3.15 ± 0.36 <sup>c,5</sup>
T <sub>1</sub>	1.26 ± 0.25 <sup>a,1</sup>	1.36 ± 0.35 <sup>a,1</sup>	1.95 ± 0.41 <sup>b,2</sup>	2.45 ± 0.25 <sup>b,3</sup>	2.89 ± 0.46 <sup>b,4</sup>
T <sub>2</sub>	1.28 ± 0.26 <sup>a,1</sup>	1.35 ± 0.36 <sup>a,1</sup>	1.73 ± 0.21 <sup>a,2</sup>	2.48 ± 0.40 <sup>b,3</sup>	2.81 ± 0.72 <sup>b,4</sup>
T <sub>3</sub>	1.26 ± 0.30 <sup>a,1</sup>	1.29 ± 0.42 <sup>a,1</sup>	1.72 ± 0.45 <sup>a,2</sup>	2.35 ± 0.45 <sup>a,3</sup>	2.52 ± 0.68 <sup>a,4</sup>
T <sub>4</sub>	1.25 ± 0.35 <sup>a,1</sup>	1.27 ± 0.25 <sup>a,1</sup>	1.55 ± 0.26 <sup>a,2</sup>	2.19 ± 0.15 <sup>a,3</sup>	2.33 ± 0.31 <sup>a,4</sup>

T<sub>0</sub>= Control, T<sub>1</sub>= 10% aloe vera gel and 1 mmol SA, T<sub>2</sub>= 20% aloe vera gel and 1 mmol SA, T<sub>3</sub>= 10% aloe vera gel and 2 mmol SA, T<sub>4</sub>= 20% aloe vera gel and 2 mmol SA; Values are mean ± SD

Values within treatments in a column not sharing a common superscript lowercase letter (a/e) are significantly ( $p \leq 0.05$ ) different.

Values within storage periods in a row not sharing a common superscript numerical (1/5) are significantly

**3.8 Microbial count (log cfu/g)**

Table 5 depicted the impact of aloe vera gel and salicylic acid-based coating on the microbial load (log cfu/g) of tomatoes during 28 days of cold storage. Initially, on day 0, the microbial load was consistent across all treatments, ranging from 1.25 to 1.28 log cfu/g. After 7

days, there was an increase in microbial growth across all treatments, with T<sub>0</sub> exhibiting the highest microbial load at 1.75 log cfu/g, followed by T<sub>1</sub> at 1.36 log cfu/g and T<sub>2</sub> at 1.35 log cfu/g. Treatments T<sub>3</sub> and T<sub>4</sub> observed less increases, recording values of 1.29 and 1.27 log cfu/g, respectively. By day 14, microbial loads continued to increase in all treatments. T<sub>0</sub> observed the highest microbial load at 2.25 log cfu/g,

while  $T_1$  and  $T_2$  recorded 1.95 and 1.73 log cfu/g of microbial load, respectively. Also,  $T_3$  and  $T_4$  had lower microbial growth, with values of 1.72 and 1.55 log cfu/g. On day 21, the microbial load further increased across all treatments.  $T_0$  again observed the highest value at 2.65 log cfu/g, followed by  $T_1$  at 2.45 log cfu/g and  $T_2$  at 2.48 log cfu/g.  $T_3$  and  $T_4$  had lower values of microbial growth at 2.35 and 2.19 log cfu/g, respectively. By day 28, the highest microbial growth was observed in  $T_0$  at 3.15 log cfu/g, followed by  $T_1$  at 2.89 log cfu/g,  $T_2$  at 2.81 log cfu/g,  $T_3$  at 2.52 log cfu/g, and  $T_4$  at 2.33 log cfu/g. The overall mean microbial load was lowest in  $T_4$  at 1.80 log cfu/g, followed by  $T_3$  at 1.83 log cfu/g,  $T_2$  at 1.93 log cfu/g,  $T_1$  at 1.98 log cfu/g, and  $T_0$  at 2.21 log cfu/g. These findings indicate that aloe vera gel and salicylic acid-based coating, is effective in reducing microbial growth, with  $T_4$  demonstrating the best control of microbial load during storage.

#### 4. Discussion

The application of aloe vera gel and salicylic acid-based coating, considerably reduced the rate of firmness loss, indicating that these treatments may be a useful postharvest procedure for preserving tomato quality and prolonging shelf-life. Physiological and biochemical reactions of fruit naturally cause its firmness to decrease during storage, and the polygalacturonase enzyme is essential to this activity (Paniagua *et al.*, 2020). Alginate-based coatings applied to table grapes and cherries have demonstrated identical outcomes, reducing firmness loss as well as delaying colour degradations (Valverde *et al.*, 2005; Serrano *et al.*, 2006). The coating lowered the respiration rate of fruit during postharvest storage which slowed down the progression of maturation thus preserving firmness of fruit (Malvano *et al.*, 2022). Decreased moisture loss enabled tomatoes treated with aloe vera gel and salicylic acid-based coating, maintain an increased turgor pressure along with enhanced cell wall integrity, which in turn-maintained firmness (Thorat *et al.*, 2024). According to the outcomes provided by Thorat *et al.* (2024), the control sample had greater amounts of weight loss than the aloe vera gel and salicylic acid based coated samples, which had a lower weight loss than the other treatments. Aloe vera gel coating works well as a moisture hurdle as was investigated by Rehman *et al.* (2020). Farooq *et al.* (2023) has demonstrated that this kind of coating considerably reduces fresh product reduction in weight. Also, salicylic acid has a positive effect on the physiological weight loss in fruits and vegetables during storage, essentially extending their shelf-life thereby inhibiting ethylene production and maintaining their quality through mechanisms like reducing respiration rate and preventing tissue breakdown (Parveen *et al.*, 2024).

Aloe vera gel-based coatings proved to be highly effective in minimizing decay in tomatoes during cold storage. The coating preserved the integrity of the cell walls, which contributed to a slower rate of firmness loss. Additionally, aloe vera gel and salicylic acid-based coating has the capacity to reduce respiration and ethylene production rates. The cell walls have been reinforced by these combined effects, increasing their resistance to infections from fungi. Additionally, fresh tomatoes proved more susceptible to pathogenic infections due to coatings as these coatings resulted in delaying the onset of senescence (Hassan *et al.*, 2014). Over storage progression, tomatoes treated with aloe vera gel and salicylic acid-based coating had a lower lycopene degradation than the other samples. This is because aloe vera gel and salicylic acid-based coating works well as a

gas barrier, lowering ethylene emissions and perhaps delaying the maturation (Parveen *et al.*, 2024; Chrysargyris *et al.*, 2016). In contrast, the early increase in lycopene content observed in the control fruits may be due to their quick ripening, leading to lycopene accumulation as the internal cell membranes transform chloroplasts into chromoplasts. Moreover, the rate of respiration during storage has been found to influence lycopene synthesis (Javanmardi and Kubota, 2006). As chloroplasts convert to chromoplasts, ripening is characterized by a rapid increase in carotenoids particularly lycopene, accompanied by a decline in chlorophyll content (Frusciante *et al.*, 2007). Aloe vera gel and salicylic acid-based coating plays a big role in preserving lycopene content in fruit like tomato during storage by delaying the ripening process thereby preserving lycopene content and enhancing the antioxidant activity (Sharma *et al.*, 2023; Nandhini and Anitha., 2021).

The initial rise in total soluble solids (TSS) during storage is due to water loss and the conversion of starch into soluble sugars during ripening. Later, TSS declines as sugars are oxidized during respiration and used as energy source for fungal growth (Singh and Sudhakar Rao, 2005). Hussain *et al.* (2013) reported a similar trend in plums. Aloe vera gel and salicylic acid-based coatings slowed TSS accumulation by limiting gaseous exchange, reducing respiration, and delaying ripening while minimizing moisture loss. Salicylic acid generally has a positive effect on TSS as it can help maintain or even increase the sugar content in fruits often leading to improved fruit quality and extended shelf-life when applied as a post-harvest treatment. The decline in DPPH radical scavenging activity over time is linked to the oxidation of phenolic compounds and ascorbic acid (Shafique *et al.*, 2016) Harrison and Were, (2007) noted a positive correlation between phenolic content and antioxidant activity, a trend also observed by Aly *et al.* (2019) in eggplants. Edible coatings help maintain higher antioxidant activity by slowing fruit metabolism. Salicylic acid generally leads to an increase in antioxidant activity by enhancing the fruit's ability to combat oxidative stress by boosting the production of antioxidant compounds like phenolic acids, flavonoids and ascorbic acid as well as stimulating the activity of antioxidant enzymes like peroxidase and super oxide dismutase. Due to its antioxidant function and activity, ascorbic acid levels decrease with storage and enzymes like ascorbate oxidase and phenol oxidase, convert it into dehydroascorbate which is biologically less active (Davey *et al.*, 2000; Suseno *et al.*, 2014, Gonzalez-Aguilar *et al.*, 2010). Similar reductions were observed in citrus fruits by Ladaniya *et al.* (2003). Edible coatings minimize vitamin C oxidation by reducing oxygen permeability and enzyme activity (Wang and Gao, 2013). Peel color changes during storage as a result of breakdown of chlorophyll and the formation of anthocyanin pigments. These changes are key indicators of fruit quality (Rastegar *et al.*, 2019). Aloe vera gel slows down ripening, delaying anthocyanin synthesis and chlorophyll breakdown, as was observed in strawberries by Nazoori *et al.* (2020).

Aloe vera gel and salicylic acid shows strong antimicrobial properties, delaying parasitic activity and inhibiting bacterial growth by blocking gas exchange (Wang *et al.*, 2020). Additionally, it lowers respiration and ethylene production, strengthening cell walls and making them more resistant to fungal invasion (Hassan *et al.*, 2014).

## 5. Conclusion

The application of aloe vera gel and salicylic acid treatment as an alternative bio-preservative covering to extend tomato longevity was investigated in this study. According to the results, aloe vera gel and salicylic acid coating considerably reduced weight loss while maintaining internal quality and firmness throughout storage progression. When compared to the control, aloe vera gel and salicylic acid-based coating was successful in retarding ripening and lowering the incidence and extent of disease infestation. The ripening process was slowed down by the aloe vera gel's ability to act as a barrier against oxygen and humidity and preventing microbial growth. 2 mmol salicylic acid and 20% aloe vera gel coating was overall the most effective treatment at preserving the nutritional value of tomatoes among the treatments. This natural coating offers a viable and environmentally responsible way to increase the shelf-life and market value of tomatoes, as per the above findings. These coatings may be easier to integrate into commercial postharvest management systems if more research is done on their widespread uses and popularity among customers.

The use of salicylic acid and aloe vera gel as a natural coating for tomatoes offers a promising, eco-friendly approach to extending their shelf-life while preserving nutritional and antioxidant properties. Tomatoes are highly perishable, often experiencing weight loss, softening, and microbial decay during storage. However, this natural coating helps slow down moisture loss, respiration rate, and oxidative degradation, which in turn maintains the fruit's firmness and quality for a longer duration. Aloe vera gel acts as a semi-permeable barrier, reducing dehydration and preventing rapid deterioration, while salicylic acid (SA) enhances the fruit's natural defense mechanisms, delaying ripening and minimizing spoilage. Unlike synthetic preservatives, which may leave harmful residues, this biodegradable and chemical-free coating provides a safer and more sustainable alternative for food preservation.

Consumers can benefit significantly from this innovation, as tomatoes remain fresher for longer periods, retaining their antioxidant properties such as vitamin C, lycopene, and polyphenols, which contribute to better health by reducing oxidative stress. Additionally, by slowing down spoilage, this method helps households, restaurants, and retailers cut down on food waste, ultimately leading to cost savings and reduced frequency of grocery purchases. Beyond personal advantages, this technique aligns with the growing need for sustainable food systems, as it reduces post-harvest losses, supports environmentally friendly food preservation methods, and lowers dependency on artificial preservatives. Overall, the integration of aloe vera and salicylic acid-based coatings is a practical, health-conscious, and sustainable solution that benefits both consumers and the food industry while contributing to a greener future.

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## Conflict of interest

The authors declare no conflict of interest relevant to this article.

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