

Extending Tomato Freshness: The Role of Aloe Vera Gel in Reducing Post-Harvest Losses

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Tomatoes are widely consumed but highly perishable due to their rapid respiration and delicate skin, causing significant post-harvest losses. Sustainable preservation is essential to maintain quality and reduce food waste. This study investigated aloe vera gel (AVG) as a natural, edible coating to extend tomato shelf life. Tomatoes at the pink ripening stage were coated with AVG for 3 and 6 minutes, then stored at 10 °C and 85% relative humidity for 16 days. The physicochemical traits pH, firmness, moisture content, total soluble solids (TSS), and microbial load were assessed every four days. AVG coatings slowed declines in pH, firmness, and moisture content compared to controls ($p < 0.05$). Non-coated tomatoes dropped from pH 4.48 to 2.87, while 3- and 6-minute coated samples retained higher pH (3.28 and 3.65). Firmness fell to 0.56 kg/cm² in controls, but coated samples retained 1.18 and 1.50 kg/cm². Coated tomatoes had higher final moisture (78.35 to 80.25%) than controls (70.45%) and less weight loss (29.55 to 30.26 g vs. 28.11 g). TSS levels remained higher in coated tomatoes (3.10 to 3.40 °Brix vs. 2.40 °Brix), with lower microbial counts (2.95 and 2.16 vs. 4.24 log CFU/g). These results support AVG as an effective, eco-friendly method for preserving tomato quality.

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INTRODUCTION

Climacteric fruits such as tomatoes (Variety PKM 1) are highly perishable, typically lasting only 7 to 10 days. Their rapid quality decline under ambient conditions stems from ethylene sensitivity, a hormone that accelerates post-harvest ripening (Mathur and Chugh 2020). To maintain the quality of tomatoes through to their commercial distribution, it is imperative to decelerate this ripening. Tomatoes are rich in essential

nutrients—such as ascorbic acid, sugars, phenolic compounds, flavonoids, carotenoids, and lycopene—necessitating careful handling to preserve their structural integrity (Ali *et al.* 2021). Key cell wall components, such as pectin, are critical for maintaining firmness; however, their degradation due to unfavourable storage conditions and microbial or fungal infections leads to significant post-harvest losses (Wang *et al.* 2023).

In recent years, significant advances have been made in the development of sustainable agricultural practices and food preservation techniques. Aloe vera, traditionally valued for its medicinal and cosmetic properties, has gained attention as a viable natural coating for extending the shelf life of fruits and vegetables. Aloe vera gel, extracted from *Aloe barbadensis* Miller leaves, contains bioactive compounds such as antioxidants, vitamins, enzymes, and polysaccharides. These compounds have potential antimicrobial properties that can mitigate microbial growth and oxidative damage in coated produce (Laux *et al.* 2019). Edible coatings are well-documented for extending the shelf life of perishable produce. These coatings function by creating a barrier that reduces the exchange of gases, solutes, and moisture. This regulation impacts factors such as oxidation rates, respiration, ethylene production, texture, flavour quality, and water loss (Kotiyal and Singh 2023).

Aloe vera gel coatings (AVGC) offer notable advantages over synthetic chemicals and preservatives, which have raised concerns about their potential adverse effects on human health and the environment. The AVGC has been demonstrated to effectively reduce weight loss and delay the ripening of climacteric fruits by slowing respiration rates and ethylene production, both of which are critical factors in the ripening process (Mendy *et al.* 2019). This delay in ripening appears to be largely due to the aloe vera gel's ability to form a semipermeable barrier on the fruit surface, which slows down gas exchange, particularly the intake of oxygen and release of carbon dioxide. By limiting oxygen availability, the coating helps reduce respiration rates and metabolic activity, thus delaying ripening. Furthermore, the restricted gas diffusion can reduce the accumulation and action of ethylene, the key hormone responsible for initiating and regulating the ripening process in climacteric fruits. By controlling both respiration and ethylene-related changes, aloe vera gel coatings effectively extend the shelf life and maintain the postharvest quality of tomatoes. This makes aloe vera a sustainable and eco-friendly alternative for extending the shelf life of perishable produce without compromising its quality. In addition to its established wound-healing properties, recent research has highlighted the antioxidant, antimicrobial, and antidiabetic activities of aloe vera, which have become the focus of bioactivity studies on the plant in recent years. Preliminary investigations also suggest immune-modulatory functions and other health benefits associated with aloe vera. However, despite its promising bioactivity, challenges remain, such as scaling up cultivation and fully utilizing its biochemical compounds for widespread applications (Raksha *et al.* 2014).

Aloe vera gel, a natural hydrocolloid primarily composed of polysaccharides, has been increasingly applied in recent years as an edible coating for fruits and vegetables. As a semipermeable barrier, it regulates the exchange of gases and water vapor, thus reducing respiration and ripening processes. The gel also helps in moisture retention, preventing dehydration and maintaining the weight and hydration of the fruit. Moreover, its antioxidant properties reduce oxidative stress on the produce, preserving its nutritional compounds such as vitamins and carotenoids, while its antimicrobial properties reduce microbial growth and spoilage. This helps in maintaining the weight, firmness, and valuable nutritional compounds of the produce. Moreover, its inherent antioxidant and

antimicrobial properties make it a promising material for extending the shelf life of fruits and vegetables (Nicolau-Lapeña *et al.* 2021). Aloe vera is among the oldest known remedies for various human ailments due to its antimicrobial, antioxidant, anti-inflammatory, and functional properties. These bioactive properties have expanded its applications into diverse fields such as food preservation, sustainable packaging, cosmetics, and pharmaceuticals. In food science, aloe vera's bioactive components have been integrated into biopolymer-based edible films and coatings, serving as natural antimicrobials and preservatives. Such applications have proven effective in extending the shelf life of perishable food items and offer a sustainable alternative to synthetic chemicals. Furthermore, aloe vera is increasingly used as a bioactive component in health drinks and other beverages due to its functional properties (Kumar *et al.* 2022).

This study aimed to develop and optimize aloe vera gel-based coatings and evaluate their effects on the quality and microbiological safety of tomatoes during post-harvest storage. The idea was that through incorporating aloe vera gel, it would be possible to extend the shelf life of the tomato fruits, reduce food waste, and promote sustainable food preservation practices, contributing to more environmentally responsible agricultural systems.

EXPERIMENTAL

Materials

Tomatoes (*Solanum lycopersicum*) at the pink ripening stage, uniform in size, shape, and colour, and free from physical damage and fungal contamination, were selected for this study. All the tomatoes for this experiment were sourced from a local market in Srivilliputhur, Tamil Nadu, India.

The tomatoes were washed to remove dirt and contaminants, surface sterilized with 1% sodium hypochlorite solution for 2 to 3 min and rinsed with water (Basumatary *et al.* 2021). After drying at room temperature, they were grouped into five batches of 26 tomatoes each and stored at 10 °C for 16 days. The tomatoes had an average diameter of 4 ± 0.5 cm and an average weight of 39 ± 3 g per fruit. For aloe vera coating gel preparation, 52 aloe vera (*Aloe barbadensis* Miller) leaves, averaging 42 ± 0.4 cm in length and 140 ± 30 g in weight, were harvested from a home terrace. Each leaf was inspected for surface injuries. All chemicals for the AVGC solution were procured from Sigma Aldrich Company.

Preparation of Aloe Vera Coating Gel

The preparation of aloe vera gel was carried out following standard methods with slight modifications (Fig. 1) (Ouaabou *et al.* 2024). Aloe vera leaves were thoroughly rinsed with running water to remove debris and impurities. The outer green peel was meticulously removed using a sterilized knife, yielding 3 kg of colourless parenchyma. The hydrogel parenchyma matrix was blended with an electronic blender at 27 °C for 12 min to achieve uniform consistency. The resulting homogeneous mixture was filtered through a cloth with a 1 to 2 mm mesh size to eliminate fibres and coarse particles, producing 2.52 L of filtered aloe vera gel. The pH of the freshly prepared aloe vera gel was measured before mixing with distilled water, using a pH meter (PB-11; Sartorius, Göttingen, Germany) calibrated with standard solutions of pH 4.0 and 7.0, following the method by

the Association of Official Analytical Chemists (AOAC), as described by Farooq *et al.* (2020). The pH was found to be approximately 4.8.

Equal volumes (700 mL each) of distilled water and the filtered AVG were combined in a 1:1 ratio. This mixture was pasteurized at 70 °C for 45 min to ensure microbial safety and preservation of bioactive compounds. After pasteurization, the aloe vera coating gel solution was cooled and stored at 5 °C to prevent oxidation of phenolic compounds. Due to evaporation during pasteurization, the final volume of the aloe vera coating gel solution was reduced to approximately 550 mL after cooling. After pasteurization, the aloe vera coating gel solution was cooled and stored at 5 °C to prevent oxidation of phenolic compounds.

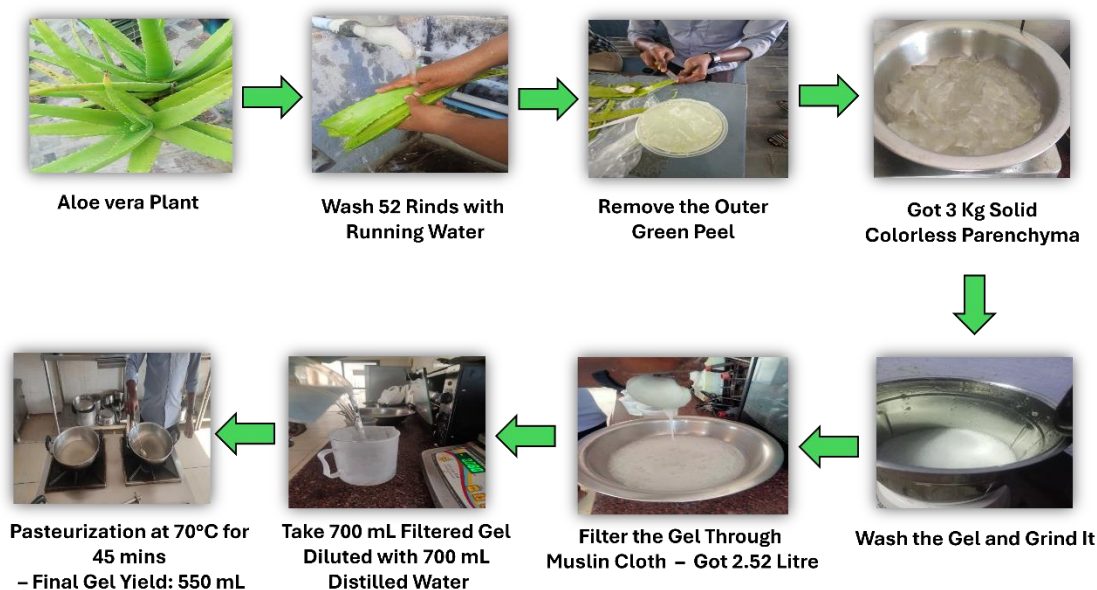


Fig. 1. Step-by-step process of aloe vera gel preparation

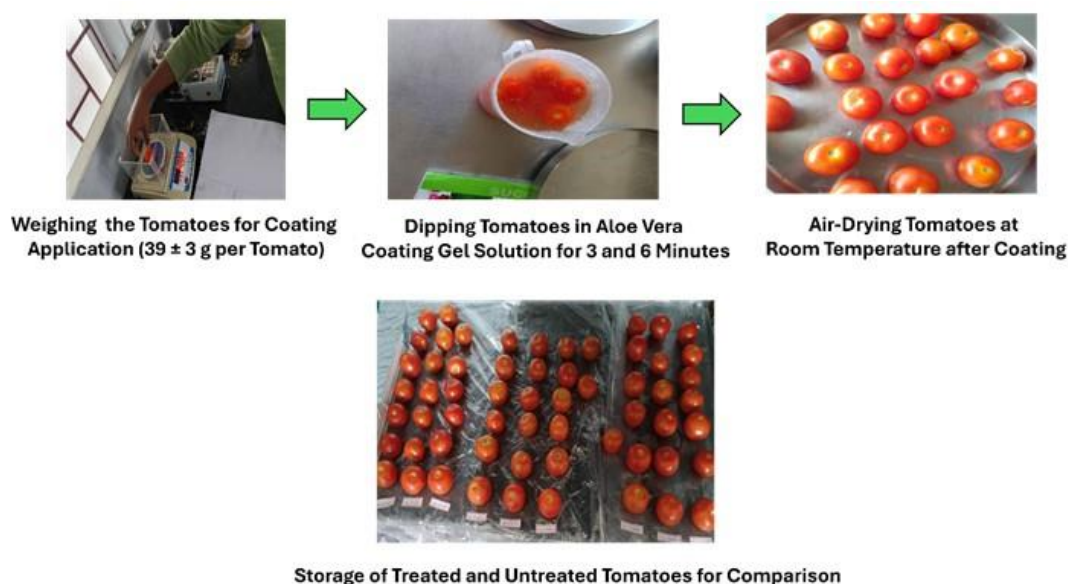


Fig. 2. Processing and application of aloe vera gel coating on tomatoes

The AVGC solutions were applied to the tomato surfaces using an immersion or dipping method for durations of either 3 min (T₃) or 6 min (T₆). An additional control group (T₀) consisted of tomatoes that were not dipped in the coating solution. The characteristics of the aloe vera gel coatings include their semipermeable nature, which regulates gas exchange and moisture loss, their antioxidant properties that protect against oxidative damage, and their antimicrobial activity that inhibits the growth of spoilage-causing microorganisms. After application, the coated tomatoes were air-dried at room temperature for 2 to 4 h, allowing the aloe vera gel to form a protective layer on the fruit's surface. Both treated and control tomatoes were then stored at 10 °C for 16 days. Figure 2 shows processing stages of aloe vera leaf for gel extraction.

Homogeneity of Coating Solutions

The homogeneity of the coating solutions was assessed using a similar approach as described by Mehryar *et al.* (2012). A 10 mL aliquot of the coating solution was placed in a plastic test tube and incubated at 25 °C. After 48 h, samples were collected from the upper and lower layers of the solution, and optical density was measured at 620 nm using a spectrophotometer (UV-1800; Shimadzu Corporation, Kyoto, Japan).

Physiological Analysis of Tomatoes: Weight Loss, Firmness, pH, Total Soluble Solids, and Moisture Content

Weight loss was assessed following the methodology described by Farooq *et al.* (2023). Fruits from each lot were weighed on the initial day and reweighed at 0, 4, 8, 12, and 16 days of storage periods (SP). The percentage of weight loss was calculated using Eq. 1:

$$\text{Weight loss(\%)} = \left(\frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}} \right) * 100 \quad (1)$$

Fruit firmness was measured using a penetrometer with a 6-mm cylindrical flat probe, inserted at three equatorial points on each fruit, and the average firmness value was recorded. The total soluble solids (TSS) content was determined using a refractometer, where three drops of tomato filtrate were placed on the prism and cleaned with distilled water and lens paper before each measurement. The pH of the tomato samples was measured using a pH meter (PB-11; Sartorius, Göttingen, Germany) calibrated with standard solutions of pH 4.0 and 7.0, following the method by the Association of Official Analytical Chemists (AOAC) as described by Farooq *et al.* (2020). Moisture content was determined according to the AOAC Official Method 925.10 (AOAC International 2019). Each parameter was measured using standardized methods to ensure the accuracy and reproducibility of the results.

Microbiological Analysis

The TMC of samples was determined from Ribeiro *et al.* (2007). Tomato samples were diluted with saline solution and spread onto nutrient agar plates. The plates were incubated at 37 °C for 48 h. After incubation, the average number of colonies was counted using a colony counter. The TMC was then calculated using Eq. 2:

$$\text{Viable bacterial count} = \left(\frac{\text{Average number of colonies} * \text{dilution factor}}{\text{Volume plated}} \right) \quad (2)$$

Statistical Analyses

Analysis of variance (ANOVA) and t-tests were used to evaluate the mean differences, with significance determined at $p < 0.05$ and a 95% confidence level. Statistical analysis of the experimental data included calculating key parameters such as the root mean square error (RMSE) and coefficient of determination (R^2) using Eqs. 3 and 4,

$$RMSE = \sqrt{\frac{\sum_{i=1}^N (EV - MV)^2}{N}} \quad (3)$$

$$R^2 = 1 - \frac{\sum_{i=1}^N (MV - EV)^2}{\sum_{i=1}^N (EV - EV_{avg})^2} \quad (4)$$

where EV represents the experimental value, MV denotes the modeled value, EV_{avg} is the average of the experimental values, and N is the number of observations.

RESULTS AND DISCUSSION

Impact of AVGC Duration on pH Values During SP

Table 1 presents the pH values of tomatoes stored under various treatment conditions over a 16-day period, illustrating the effectiveness of AVGC in maintaining pH stability. The pH of the aloe vera gel used for coating was measured at 4.5 ± 0.1 , which is slightly acidic and contributed to maintaining a favorable microenvironment on the tomato surface. Untreated control tomatoes exhibited a significant decrease in pH, from 4.48 on day 0 to 2.87 by day 16, reflecting a notable increase in acidity due to natural ripening and degradation processes. In contrast, tomatoes coated with AVGC demonstrated a significantly slower decline in pH, with those coated for 3 min showing a reduction from 4.53 to 3.28, and those coated for 6 min decreasing from 4.42 to 3.65. Statistical analysis revealed a significant difference ($p < 0.05$) between coated and uncoated tomatoes in terms of pH decline.

These results indicate that the aloe vera gel coatings were effective in mitigating the increase in acidity by minimizing oxygen exposure and moisture loss, which are key factors in the ripening process. The semipermeable nature of the aloe vera gel created a barrier that significantly reduced respiration rates and controlled moisture exchange, thereby slowing down the production of organic acids and extending the shelf life of the tomatoes. This physical barrier reduced the availability of oxygen, thus decreasing oxidative reactions and slowing down respiration rates, which in turn stabilized pH during storage. Additionally, aloe vera gel exhibited antimicrobial activity due to its bioactive constituents such as anthraquinones, flavonoids, and saponins. These compounds can disrupt microbial cell walls, inhibit microbial growth, and reduce spoilage, indirectly preserving the physicochemical quality of tomatoes.

Similar findings were reported by researchers. For instance, Sultana *et al.* (2019) found that chitosan-coated tomatoes maintained higher pH levels, indicating reduced acidity and slower ripening, while Flores *et al.* (2023) demonstrated that pectin-based coatings stabilized pH by reducing respiration rates. Padma Sree *et al.* (2022) further supported the effectiveness of AVGC by showing that combining aloe vera with chitosan coatings resulted in more stable pH levels compared to single-component coatings. This suggests that aloe vera's bioactive compounds enhance preservation when used in

conjunction with other biopolymers. Miranda *et al.* (2022) also observed that carnauba wax coatings reduced pH declines by creating a barrier to moisture and gas exchange, which corroborates the current study's findings.

The application of aloe vera gel coatings involved dipping tomatoes in the gel solution for 3 to 6 min, followed by drying at room temperature for 2 to 4 h to form a protective layer. This method effectively extends the shelf life of tomatoes and other perishable fruits by reducing ripening and microbial contamination. In commercial and small-scale agricultural settings, AVGC offers a cost-effective and sustainable alternative to synthetic preservatives, supporting organic farming practices and reducing chemical reliance. Additionally, aloe vera gel's antimicrobial and antioxidant properties make it suitable for a range of food preservation applications, including other fruits, vegetables, and even baked goods. Thus, aloe vera gel coatings provide a practical and eco-friendly solution for maintaining fruit quality and extending shelf life.

Table 1. pH Values of Coated and Uncoated Tomatoes During a 16-day Storage Period

Days	pH		
	T ₀	T ₃	T ₆
0	4.48 ^c ± 0.31	4.53 ^c ± 0.32	4.42 ^c ± 0.12
4	3.32 ^a ± 0.25	3.78 ^a ± 0.23	4.10 ^a ± 0.28
8	3.12 ^a ± 0.23	3.58 ^b ± 0.20	3.96 ^a ± 0.29
12	2.99 ^b ± 0.23	3.35 ^a ± 0.29	3.82 ^b ± 0.34
16	2.87 ^c ± 0.12	3.28 ^c ± 0.25	3.65 ^c ± 0.22

Values with different superscript letters differ significantly ($p < 0.05$). Data are mean $\pm$ SD ($n = 3$ per group).

Impact of AVGC Duration on TSS Content During SP

Table 2 show the effect of AVGC on the TSS of tomatoes over a 16-day storage period. Initially, non-coated tomatoes (control) had a TSS of 3.3 °Brix on day 0, which increased to 4.0 °Brix by day 4 before declining to 2.4 °Brix by day 16. This decline reflects reduced ripeness and sweetness, which was likely due to metabolic processes and moisture loss. In contrast, tomatoes coated with aloe vera gel for 3 and 6 min displayed different TSS trends. The 3-min coating started with a TSS of 2.2 °Brix, increased to 3.3 °Brix by day 12, and slightly decreased to 3.1 °Brix by day 16. The 6-min coating began at 2.0 °Brix, reached 3.9 °Brix by day 12, and fell to 3.4 °Brix by day 16.

Statistical analysis revealed a significant difference ($p < 0.05$) in TSS retention between coated and uncoated tomatoes. The increase in TSS for coated tomatoes, particularly those with a 6-min coating, indicated that the gel coating helped retain sugars and other soluble solids, contributing to higher sweetness and better ripeness compared to the control. The more substantial protective layer provided by the 6-min coating more effectively reduced moisture loss and slowed metabolic changes, resulting in higher TSS values. The underlying mechanism appears to involve a semipermeable barrier properties of the aloe vera gel, which reduces water vapor transmission and limits oxygen ingress. By slowing down respiration rates and ethylene production, the coating delays metabolic

degradation of sugars and preserves the TSS levels during storage. Additionally, the antioxidant compounds present in aloe vera may further stabilize internal biochemical conditions, protecting soluble solids from oxidative breakdown (Heś et al. 2019).

These findings underscore aloe vera gel's potential as an effective edible coating for preserving both firmness and sweetness during storage, thereby extending the quality and shelf life of tomatoes. Similar findings were reported by researchers. Amin *et al.* (2021) reported that natural coatings like aloe vera help retain higher TSS levels by reducing moisture loss and improving sugar retention. Sharma and Bhardwaj (2024) found that coatings based on natural polymers, such as aloe vera, effectively maintain higher TSS levels by minimizing water vapor transmission and gas exchange. Hajizadeh (2023) emphasized that controlling ethylene through various packaging methods can also preserve TSS levels during storage.

Table 2. TSS (°Brix) of Coated and Uncoated Tomatoes Over 16 Days of Storage

Days	TSS (°Brix)		
	T ₀	T ₃	T ₆
0	3.30 ^b ±0.37	2.20 ^b ±0.25	2.00 ^a ±0.05
4	4.00 ^b ±0.25	3.00 ^a ±0.19	2.80 ^a ±0.09
8	3.20 ^a ± 0.32	3.20 ^b ± 0.10	3.30 ^b ± 0.13
12	2.90 ^a ±0.24	3.30 ^a ±0.27	3.90 ^b ±0.22
16	2.40 ^b ±0.19	3.10 ^c ±0.25	3.40 ^b ±0.16

Impact of AVGC Duration on Tomato Firmness During SP

Table 3 show the impact of AVGC on the firmness of tomatoes over a 16-day storage period. Initially, non-coated tomatoes (control) had a firmness of 2.95 kg/cm², which decreased significantly to 0.56 kg/cm² by day 16, primarily due to natural ripening processes, including transpiration and respiration, leading to the degradation of cell wall structure and subsequent loss of firmness. In contrast, tomatoes coated with aloe vera gel exhibited a more gradual decline in firmness.

Tomatoes coated for 3 min showed a reduction in firmness from 2.98 kg/cm² to 1.18 kg/cm², while those coated for 6 min decreased from 2.90 kg/cm² to 1.50 kg/cm². Statistical analysis indicated a significant difference ($p < 0.05$) in firmness retention between coated and uncoated tomatoes. The slower rate of firmness loss in coated tomatoes is attributed to the aloe vera gel's role in forming a protective barrier on the fruit's surface. This barrier effectively reduces moisture loss and slows down respiration, thereby minimizing the breakdown of cell walls and preserving the fruit's structural integrity. The 6-min coating duration provided the most effective protection, resulting in a smaller reduction in firmness compared to the 3-min coating. This enhanced protection can be attributed to the thicker and more cohesive layer of aloe vera gel, which offers superior coverage and more effective control over moisture loss and ripening processes. Its semipermeable membrane properties reduce transpiration and control gas exchange, particularly oxygen intake and carbon dioxide release, thereby slowing metabolic activities such as enzymatic degradation of pectin and hemicellulose in the cell wall. Additionally,

bioactive compounds present in aloe vera, such as polysaccharides and phenolic compounds, may enhance cell wall stability by providing antioxidant protection against oxidative stress, which typically accelerates tissue softening (Bawankar *et al.* 2014).

Similar findings have been reported by other researchers. For example, Mandal *et al.* (2020) found that chitosan coatings preserved tomato firmness by creating a semi-permeable barrier that minimized water loss and respiration. Kotiyal and Singh (2023) observed that AVGC resulted in higher firmness values due to reduced moisture loss and protection against microbial spoilage. In another work, Menezes and Athmaselvi (2018) demonstrated that combining aloe vera with chitosan coatings was more effective than single-component coatings in maintaining firmness, suggesting a synergistic effect in moisture loss reduction and delay of softening. Furthermore, Miranda *et al.* (2022) showed that carnauba wax coatings slowed firmness decline by providing a barrier to moisture loss and reducing respiration rates.

Table 3. Firmness of Coated and Uncoated Tomatoes During a 16-day Storage Period

Days	Firmness (kg/cm ²)		
	T ₀	T ₃	T ₆
0	2.95 ^c ± 0.12	2.98 ^c ± 0.19	2.9 ^a ± 0.22
4	1.74 ^a ± 0.15	2.5 ^b ± 0.25	2.7 ^c ± 0.12
8	1.08 ^b ± 0.09	1.99 ^a ± 0.15	2.1 ^a ± 0.18
12	0.91 ^a ± 0.05	1.6 ^b ± 0.10	1.83 ^a ± 0.12
16	0.56 ^c ± 0.01	1.18 ^b ± 0.09	1.5 ^b ± 0.20

Impact of AVGC Duration on Moisture Content During SP

Table 4 shows the effect of AVGC on the moisture content of tomatoes throughout a 16-day storage period. Initially, uncoated tomatoes had a moisture content of 86.5%, which decreased significantly to 70.4% by day 16, primarily due to evaporation and respiration. In contrast, tomatoes coated with aloe vera gel demonstrated slower moisture loss. Specifically, tomatoes coated for 3 min started with a moisture content of 87.4% and decreased to 78.3%, while those coated for 6 min began at 88.2% and fell to 80.2%.

Statistical analysis confirmed significant differences ($p < 0.05$) in moisture loss between coated and uncoated tomatoes. Non-coated tomatoes exhibited a 16.1% reduction in moisture content, whereas the 3-min and 6-min coatings resulted in reductions of 9.1% and 8.0%, respectively. The 6-min coating duration provided the most effective protection, due to the thicker and more cohesive layer of aloe vera gel, which offered superior coverage and better control over moisture loss and ripening processes. The effectiveness of aloe vera gel in preserving moisture content can be attributed to its function as a natural semi-permeable barrier. Aloe vera gel forms a continuous film that limits water vapor transmission and restricts oxygen influx, thereby reducing transpiration and respiration rates. Polysaccharides such as acemannan and glucomannan, abundant in aloe vera gel, contribute to water retention by creating a hydrophilic matrix that retains moisture within the fruit.

Similar findings have been reported by other researchers. For example, Galus and Kadzińska (2015) demonstrated that natural polymer coatings, such as those made from chitosan and aloe vera, effectively preserved moisture content and extended fruit shelf life by reducing moisture loss and microbial growth.

In another work, Valencia-Chamorro *et al.* (2011) observed that chitosan coatings, analogous to aloe vera gel, created a semi-permeable barrier that mitigated moisture loss, highlighting the potential of aloe vera gel coatings for effective moisture retention and extended shelf life of tomatoes.

Table 4. Moisture Content of Coated and Uncoated Tomatoes During a 16-day Storage Period

Days	Moisture Content (%)		
	T ₀	T ₃	T ₆
0	86.5 ^a ± 0.25	87.45 ^b ± 0.28	88.25 ^a ± 0.24
4	80.05 ^b ± 0.25	85.65 ^c ± 0.25	86.85 ^b ± 0.23
8	76.05 ^a ± 0.19	82.55 ^c ± 0.35	84.45 ^b ± 0.45
12	74.25 ^c ± 0.28	80.45 ^b ± 0.39	82.55 ^b ± 0.31
16	70.45 ^b ± 0.36	78.35 ^c ± 0.47	80.25 ^c ± 0.27

Effect of Different Treatments on Weight During SP

Table 5 presents the impact of AVGC on weight loss in tomatoes over a 16-day storage period. Initially, uncoated tomatoes had an average weight of 36.91 g, which decreased significantly to 28.11 g by day 16, mainly due to moisture loss. This resulted in increased skin wrinkling and diminished consumer appeal. In contrast, tomatoes coated with Aloe vera gel exhibited reduced weight loss.

Tomatoes coated for 3 min started at 37.33 g and decreased to 29.55 g, while those coated for 6 min began at 38.71 g and fell to 30.26 g. Statistical analysis confirmed significant differences ($p < 0.05$) in weight loss between coated and non-coated tomatoes. The aloe vera gel coatings effectively reduced weight loss, suggesting that AVG coatings help retain moisture and reduce the rate of dehydration compared to uncoated tomatoes. Aloe vera gel forms a semi-permeable film that slows down water vapor transmission and gas exchange, thereby minimizing transpiration-driven water loss. This protective barrier also reduces the rate of respiration, further conserving internal moisture.

Similar findings have been reported. For instance, Sang and Hai (2020) demonstrated that carnauba wax coatings similarly minimized weight loss and preserved firmness, paralleling the effects of aloe vera gel. Additionally, Mendy *et al.* (2019) found that combining aloe vera with chitosan coatings provided enhanced preservation effects, including reduced respiration rates and delayed ripening. These studies underscore the efficacy of AVG and other coatings in extending the shelf life and maintaining the quality of tomatoes.

Table 5. Weight of Coated and Uncoated Tomatoes During a 16-day Storage Period

Days	Weight Loss (g)		
	T ₀	T ₃	T ₆
0	36.91 ^a ± 0.20	37.33 ^a ± 0.21	38.715 ^b ± 0.26
4	34.21 ^c ± 0.27	35.82 ^b ± 0.35	36.195 ^d ± 0.28
8	32.10 ^b ± 0.24	33.85 ^c ± 0.29	34.615 ^{ab} ± 0.21
12	30.40 ^b ± 0.41	31.02 ^b ± 0.26	33.29 ^b ± 0.28
16	28.11 ^a ± 0.34	29.55 ^a ± 0.14	30.26 ^a ± 0.23

Microbiological Analysis

Table 6 displays the microbial counts of tomatoes over a 16-day storage period, reflecting the impact of AVGC on microbial growth. Initially, no significant difference in microbial decay was observed among the treatments up to day 4. However, by day 8, a marked increase in microbial counts was noted. Uncoated tomatoes exhibited a significantly higher microbial count of 2.52 log cfu/g compared to those coated with aloe vera gel.

Specifically, tomatoes coated for 3 min had a lower count of 1.76 log cfu/g, while those coated for 6 min had the lowest count of 1.34 log cfu/g. By day 16, the microbial counts in uncoated tomatoes had risen to 4.24 log cfu/g, whereas the counts in tomatoes coated for 3 and 6 min were 2.95 and 2.16 log cfu/g, respectively. Statistical analysis confirmed significant differences ($p < 0.05$) in microbial counts between coated and uncoated tomatoes.

These findings suggest that aloe vera gel coatings effectively inhibited microbial growth and decay, with the 6-min coating duration providing the most significant reduction in microbial counts. The aloe vera coatings formed a protective barrier that not only repairs surface damage but also impedes microbial contamination. This result aligns with research by Imani and Danaee (2023), who demonstrated that chitosan-aloe vera coatings create an additional barrier against post-harvest microbial spoilage.

Table 6. Microbial Count of Coated and Uncoated Tomatoes During a 16-day Storage Period

Days	Microbial Count (cfu/g)		
	T ₀	T ₃	T ₆
0	1.07 ^c ± 0.07	1.05 ^c ± 0.06	1.01 ^c ± 0.02
4	1.59 ^b ± 0.09	1.37 ^b ± 0.08	1.15 ^d ± 0.05
8	2.52 ^b ± 0.12	1.76 ^c ± 0.09	1.34 ^a ± 0.09
12	3.63 ^c ± 0.22	2.19 ^b ± 0.16	1.56 ^b ± 0.07
16	4.24 ^b ± 0.09	2.95 ^c ± 0.11	2.16 ^c ± 0.08

Homogeneity

The homogeneity of AVGC solutions applied for 3 min (T3) and 6 min (T6) was assessed during a 16-day storage period at 10 °C, in comparison to uncoated tomatoes (T0).

Optical density (OD) at 620 nm was measured after 48 h to determine the uniformity and stability of the coating across the tomato surface.

As shown in Table 7, the uncoated tomatoes (T0) exhibited significant instability, with OD values of 2.89 ± 0.03 in the upper portion and 0.96 ± 0.05 in the lower portion, indicating non-uniform moisture distribution and an unstable surface. In contrast, the coated samples, both T3 and T6, demonstrated a significant improvement in homogeneity, with stable OD values that reflected even coating distribution.

For T3, the OD values were 0.72 ± 0.02 in the upper portion and 0.68 ± 0.01 in the lower portion, while T6 showed 0.63 ± 0.04 (upper) and 0.59 ± 0.05 (lower), indicating a more consistent and cohesive application. Statistical analysis revealed a significant difference ($p < 0.05$) in stability between coated and uncoated tomatoes, confirming that the AVGC effectively enhanced surface uniformity, particularly with the 6-min coating.

Table 7. Homogeneity Values for Uncoated and Coated Tomatoes Stored at 10 °C For Up to 16 Days

Sample	O.D 620 nm at 48h		
	Upper	Lower	Stability
T ₀	2.89 ± 0.03	0.96 ± 0.05	Unstable
T ₃	0.72 ± 0.02	0.68 ± 0.01	Stable
T ₆	0.63 ± 0.04	0.59 ± 0.05	Stable

CONCLUSIONS

1. This study demonstrated that aloe vera gel coatings (AVGC) effectively extend tomato shelf life and preserve quality at $13 \pm 2^\circ\text{C}$
2. The results highlight that the duration of the coating application, particularly the 6-minute treatment, positively affected key preservation parameters, including pH stability, firmness, moisture retention, weight loss reduction, and microbial inhibition.
3. Tomatoes treated with AVGC showed better pH stability, with the 6-min coated samples exhibiting a slower increase in acidity compared to uncoated tomatoes. This can be attributed to the semipermeable barrier created by the aloe vera gel, which reduces oxygen exposure, slows respiration, and minimizes moisture loss, ultimately delaying the ripening process.
4. In terms of firmness, AVGC-treated tomatoes retained their structural integrity for a longer period, with the 6-min treatment proving most effective in reducing the breakdown of cell walls and moisture loss, thereby delaying softening.
5. The aloe vera coating effectively mitigated moisture loss and weight reduction, with coated tomatoes showing significantly higher moisture content and less weight loss than the uncoated control group. This was particularly evident in the 6-min coating, which formed a thicker, more cohesive protective layer, limiting water vapor transmission and gas exchange, resulting in better preservation of the tomatoes.
6. The antimicrobial properties of aloe vera were also confirmed, as coated tomatoes exhibited significantly lower microbial counts compared to uncoated ones, with the 6-min coating offering the most pronounced reduction in microbial contamination.

As a result, the shelf life of AVGC-treated tomatoes was extended by up to 21 days compared to the uncoated control.

7. Aloe vera gel coatings, particularly with a 6-min application, offer a sustainable, eco-friendly alternative to synthetic preservatives. By effectively maintaining tomato quality through reduced ripening, moisture retention, improved firmness, enhanced sweetness, and controlled microbial growth, this study supports the use of aloe vera gel as a practical solution for post-harvest preservation in both commercial and agricultural settings.

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