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The Application of Potato Starch-Based (*Amylum solani*) Edible Coating on Tomatoes (*Solanum lycopersicum* L.)

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ABSTRACT

This study investigates the potential of potato starch-based edible coatings (Amylum solani) to extend the shelf life and preserve the quality of tomatoes (Solanum lycopersicum L.*) during storage. The experiment contributed to evaluating the effect of the coating on critical quality parameters, including weight loss, firmness, color stability, moisture content, vitamin C retention, and sensory characteristics. Tomatoes with edible coatings exhibited a slower rate of weight loss compared to uncoated samples, which is attributed to the coating's ability to form a protective barrier that minimizes water evaporation and respiration rates. Coated tomatoes also retained firmness more effectively, delaying the softening process caused by metabolic and enzymatic activity. The study revealed that the edible coating reduced the rate of color degradation by slowing the loss of chlorophyll and the formation of lycopene, preserving the tomatoes' visual appeal. Moreover, the coating significantly delayed the decline in vitamin C content by inhibiting oxidation and maintaining structural integrity, which was further reflected in the higher sensory scores for coated tomatoes. Organoleptic tests indicated that panelists preferred coated tomatoes due to their glossy appearance, firmer texture, and sweeter taste, although these preferences gradually decreased over time. Analysis showed that the coating extended the shelf life of tomatoes to 13.64 days, compared to 9.76 days for uncoated samples. These results highlight the efficacy of potato starch-based edible coatings as an environmentally friendly and cost-effective solution for reducing postharvest losses, meeting consumer demand for fresh produce, and improving food security. This study provides valuable insights into the practical application of edible coatings for preserving climacteric fruits such as tomatoes, with implications for sustainable agricultural practices.*

KEYWORDS
Edible coating; Potato starch; Shelf life; Tomato; Vitamin C

1. INTRODUCTION

With the changing times, public awareness of the importance of nutrition in their diet has increased, as evidenced by the growing interest in high-quality fruits and vegetables. To meet this demand, it is not only necessary to improve the production of fruits and vegetables but also to develop strategies to maintain their quality for the market.

Tomatoes are classified as vegetables with high commodity and economic value. They produce fruit only once per harvest season [1]. Tomatoes are an essential ingredient in many dishes and beverages due to their rich nutritional content. However, their high water content makes them highly perishable. Fresh tomatoes can typically be stored for only three to four days, while high-quality ones may last up to six to seven days. Therefore, postharvest care is crucial to maintain their quality. The use of edible coatings, such as those made from taro starch, has been shown to preserve the internal condition of tomatoes for up to 14 days, significantly longer than untreated tomatoes [2]. This makes edible coatings an effective method for extending the shelf life of tomatoes.

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Tomatoes (*Solanum lycopersicum* L.) are a vital component of global diets due to their nutritional richness and culinary versatility. However, their high respiration rate and moisture content make them highly perishable, resulting in significant postharvest losses [3], [4]. To mitigate these losses, various preservation techniques have been developed, with edible coatings gaining particular attention for their ability to extend shelf life and maintain quality [5].

Tomatoes are climacteric fruits characterized by a rise in respiration and ethylene production during ripening, leading to rapid spoilage [6]. This perishability poses challenges in postharvest handling and storage. Traditional preservation methods, such as refrigeration or chemical treatments, often face limitations, including high energy requirements, potential chemical residues, and environmental concerns [7]. As a result, there is growing interest in sustainable alternatives like edible coatings. Edible coating is a more environmentally friendly preservation method.

Starch, a polysaccharide composed of amylose and amylopectin, is extensively used in edible coatings due to its natural film-forming capabilities, edibility, and biodegradability [8], [9]. Potato starch, in particular, is a promising candidate with a starch content of 22–28%, consisting of approximately 21.04% amylose and 78.96% amylopectin [10], [11], [12]. Amylose contributes to the strength and gas barrier properties of coatings, while amylopectin enhances flexibility and moisture resistance [13]. Despite these advantages, starch-based coatings are inherently brittle and hydrophilic, requiring modifications to improve their performance [14].

Plasticizers like glycerol are commonly added to starch-based coatings to enhance flexibility and reduce brittleness by disrupting intermolecular forces within the starch matrix [15], [16], [17]. Furthermore, blending starch with other biopolymers or incorporating lipids can improve water vapor barrier properties and mechanical strength [18]. For example, studies have shown that incorporating natural extracts with antimicrobial properties into starch-based coatings can inhibit microbial growth on tomatoes, further extending their shelf life [5].

Research on the application of potato starch-based edible coatings for tomatoes has demonstrated promising results. Such coatings significantly reduce weight loss, maintain firmness, and delay color changes during storage [4]. Factors such as starch concentration, type and amount of plasticizer, and the inclusion of bioactive compounds are critical in determining the coating's effectiveness. The development and optimization of these coatings hold great potential for reducing postharvest losses and meeting consumer demand for fresh, high-quality produce [6].

This research contribution is to evaluate the effectiveness of potato starch-based edible coatings in preserving the quality and extending the shelf life of tomatoes under different storage durations. Specifically, the study aims to assess the impact of the edible coating on key parameters such as weight loss, color stability, and overall quality during a storage period of up to 18 days. The research seeks to determine whether the application of edible coatings significantly improves the postharvest characteristics of tomatoes compared to uncoated samples and to identify the optimal storage duration for maintaining tomato quality.

2. MATERIALS AND METHODS

2.1. Materials

The materials required for this research include tomatoes, potato starch, distilled water, glycerol, stearic acid, carboxymethyl cellulose (CMC), 0.01 N iodine solution, and potassium sorbate. These materials were procured from local markets and suppliers, including CV Surya Artathama and CV Sentra Teknosains.

2.2. Edible Coating Preparation

To prepare the edible coating solution, the required amounts of glycerol, distilled water, potato starch, CMC, stearic acid, and potassium sorbate were calculated. A hot plate was preheated to approximately 70 °C, with the temperature monitored using a thermometer. CMC was added at 0.4% (2.8 g) as an emulsifier and stabilizer, and the mixture was stirred for over 3 minutes. Potato starch was gradually added at 4% (28 g) over approximately 3 minutes. Glycerol (50 mL) was then introduced as a crystallization agent and plasticizer. Potassium sorbate at 0.4% (2.8 g) was incorporated to inhibit microbial growth on the fruit, and the solution was stirred for about one minute. Finally, stearic acid at 0.5% (3.5 g) was added to the mixture to reduce water vapor transmission, and the solution was stirred until homogeneous for approximately 6 minutes.

2.3. Color Analysis

The color of the tomatoes was measured using a chromameter. For the analysis, the product was placed on white paper, and measurements were conducted with a colorimeter. The device provided values for the parameters L^*, a^*, and b^*. The L^* value indicates brightness (achromatic color, where 0 represents black and 100 represents white). The a^* value reflects the red-green chromatic component (a+ = 0 to 100 for red; a- = 0 to -80 for green). Similarly, the b^* value represents the yellow-blue chromatic component (b+ = 0 to 70 for yellow; b- = 0 to -70 for blue) [19].

2.4. Weight Loss Analysis

Weight loss was calculated by subtracting the final weight from the initial weight. The result was then divided by the initial weight and multiplied by 100 to express the weight loss as a percentage [20].

2.5. Firmness Analysis

The firmness of the tomatoes was tested using a force gauge. This device measures the amount of pressure required to compress the surface of the tomato, indicating the fruit's firmness [21], [22].

2.6. Moisture Content Analysis

Moisture content was measured using a thermogravimetric method [23]. The process began with drying the sample in an oven at 105 °C for 1 hour. The sample was then cooled in a desiccator for 30 minutes and weighed. A sample weighing 5 g was placed in the dish and dried in the oven at 105 °C for 3 hours, cooled in a desiccator for 1 hour, and weighed. The sample was then returned to the oven for an additional hour at 105 °C, cooled in the desiccator for 30 minutes, and weighed again. This process was repeated until a constant weight was achieved [24].

2.7. Vitamin C Analysis

Vitamin C content was measured by titration method. A 10 g sample was crushed using a mortar, mixed with 100 mL of distilled water, and transferred into a volumetric flask. The mortar was rinsed with distilled water to ensure complete transfer, and the solution was filtered. A 10 mL aliquot of the filtrate was taken, and 1 mL of starch solution was added to an erlenmeyer flask. The solution was then titrated with 0.01 N iodine solution until a color change was observed. Each mL of 0.01 N iodine solution corresponds to 0.88 mg of ascorbic acid [20].

2.8. Organoleptic Test

Nine tomato samples coated with potato starch-based edible coatings were presented to 20 panelists for sensory evaluation. The panelists assessed their preferences for color by observing, texture by pressing, taste by tasting, and aroma by smelling the samples. Each panelist rated their preferences using a 7-point scale, with scores ranging from 1 (least preferred) to 7 (most preferred).

2.9. Data Analysis

The data analysis was conducted using a Completely Randomized Design (CRD) with two factors. The first factor was the application of edible coating, consisting of two levels: tomatoes without edible coating (A1) and tomatoes with edible coating (A2). The second factor was the storage duration, which included seven levels: 0 days (B1), 3 days (B2), 6 days (B3), 9 days (B4), 12 days (B5), 15 days (B6), and 18 days (B7). This experimental setup resulted in a total of 28 experimental units. The data collected from observations were analyzed statistically using Analysis of Variance (ANOVA). If significant differences were found, Duncan's Multiple Range Test (DMRT) was performed at a 5% significance level to identify specific treatment effects.

3. RESULTS AND DISCUSSION

3.1. Color

Color analysis is a method used to evaluate unknown samples by referencing known color standards. Essentially, it is a comparative technique that assesses the sample's characteristics against a standard color. Edible coatings can help slow down the respiration process, which otherwise accelerates the ripening of tomatoes and increases color degradation. During storage and from Figure 1, the respiration rate rises, leading to the loss of chlorophyll and the formation of red pigmentation. According to Kapoor et al., (2022) [25], the transition from chlorophyll to lycopene is responsible for the reddish coloration of the fruit. Lycopene, a key indicator of redness, signifies a higher lycopene content and is associated with the ripening process.

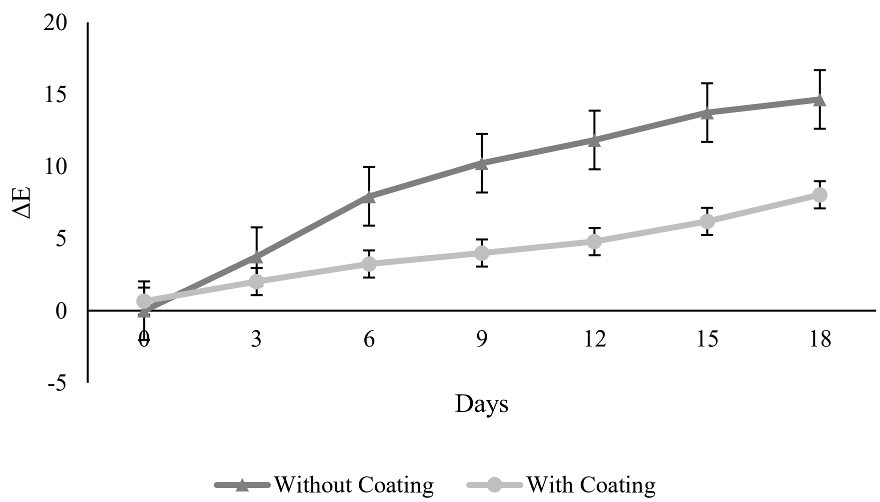

Figure 1. Color difference from tomato during storage.

The type of treatment and storage duration significantly influence the firmness of tomatoes, as demonstrated by a two-way ANOVA conducted at the 5% significance level. This effect is likely due to the ability of edible coatings to slow down the respiration process, which otherwise accelerates ripening and results in a faster loss of firmness in tomatoes.

The graph in Figure 1 illustrates the color difference (ΔE) in tomatoes during storage, comparing those with and without an edible coating. Tomatoes without coating (dark grey line) exhibited a rapid increase in ΔE, indicating significant color changes over time, with the highest difference observed at 18 days. In contrast, tomatoes with an edible coating (grey line) demonstrated a slower progression in color changes, maintaining a lower ΔE throughout the storage period. This suggests that the edible coating effectively reduces color degradation and delays ripening, thereby preserving the visual quality of the tomatoes during extended storage. The differences in tomato color are represented in Figure 2.

These findings align with previous research indicating that edible coatings can significantly delay color changes in tomatoes. For instance, a study by Dávila-Aviña et al., (2011) [26] found that mineral oil coatings delayed color changes and reduced weight losses in tomatoes stored at 10°C. Edible composite coatings effectively slowed down color change in chili during storage [4]. These studies support the conclusion that edible coatings are beneficial in maintaining the visual quality of tomatoes over extended storage periods.

Figure 2. Color difference from tomato without coating (left) and with coating (right).

3.2. Weight Loss

Respiration in fruit involves the absorption of oxygen to oxidize organic compounds, generating energy in the process. As a result of this metabolic activity, carbon dioxide and water are released as byproducts. Factors such as the fruit's surface area-to-volume ratio, the natural surface coating, and mechanical damage to the skin significantly influence the rate of water loss. The application of an edible coating is expected to slow down the rate of weight loss by acting as a protective barrier, reducing moisture loss, and preserving the fruit's overall quality.

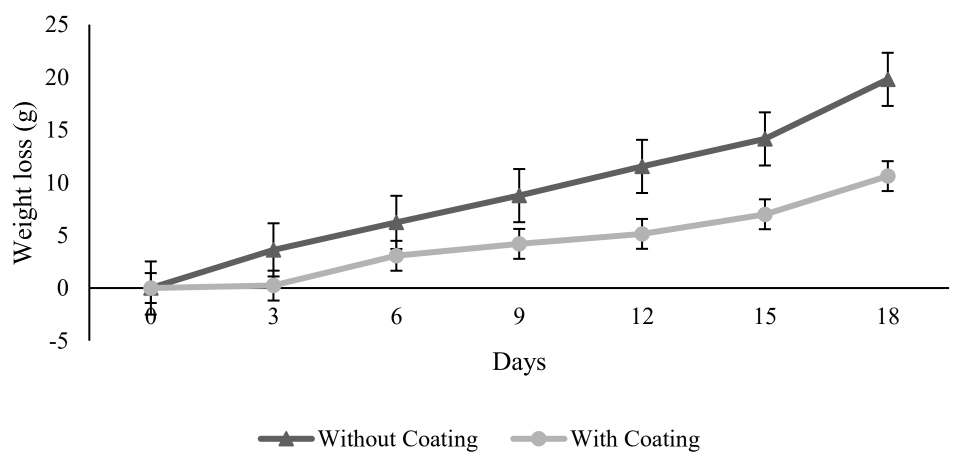

Figure 3. Weight losses from tomatoes during storage.

Based on Figure 3, the results indicate that the greatest weight loss occurred on the final day of storage for tomatoes without an edible coating. This significant weight loss is attributed to water loss caused by transpiration or evaporation of water from the fruit tissues. Water loss can lead to fruit wilting and wrinkling [27].

The type of treatment and storage duration had a highly significant effect on weight loss, as demonstrated by the results of the two-way ANOVA conducted at the 5% significance level. This finding underscores the effectiveness of edible coatings in reducing water loss during storage by forming a barrier that minimizes transpiration and evaporation.

The application of edible coatings has been shown to mitigate weight loss in tomatoes during storage effectively. For instance, a study by Lakshan et al., (2024) [28] demonstrated that tomatoes coated with an arrowroot starch-beeswax-based edible coating enriched with clove essential oil exhibited significantly reduced weight loss compared to uncoated fruits. The coating acted as a barrier to moisture loss, thereby preserving the fruit's firmness and overall quality during storage.

Similarly, research by Sultan et al., (2021) [29] found that chitosan and beeswax-based edible coatings effectively reduced weight loss in Le Conte pears by creating a semi-permeable barrier that minimized respiration and transpiration rates. This approach helped maintain the fruit's texture and appearance over an extended storage period. These findings underscore the importance of edible coatings in extending the shelf life of perishable fruits like tomatoes by reducing moisture loss and maintaining postharvest quality.

3.3. Firmness

The firmness of fruit is a critical parameter influencing consumer acceptance of fruits and vegetables. During ripening, fruit firmness plays a significant role in determining susceptibility to contamination and overall shelf life [30]. Tomatoes typically soften as their storage duration increases. This reduction in firmness is attributed to metabolic processes, including respiration, the breakdown of carbohydrates, proteins, and fats, as well as a decline in water content. Additionally, microorganisms that degrade the cellular structure of the fruit contribute to the loss of firmness [31].

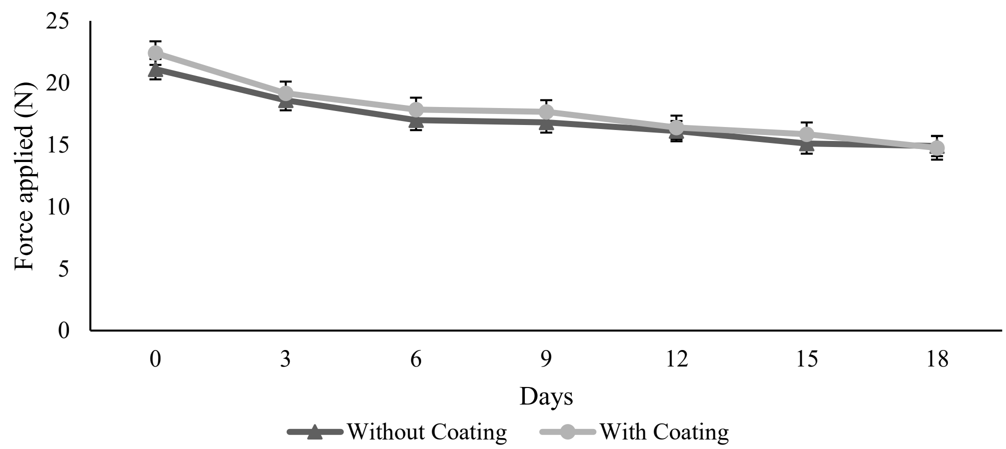

Figure 4. Firmness of tomato during storage.

Based on Figure 4, the firmness of tomatoes decreased throughout the storage period. The firmness levels declined across all treatments, with tomatoes becoming softer by day 18 as they ripen further. Initially, the coated tomatoes required a force of approximately 25 N, which gradually decreased to around 15 N by day 18. In contrast, uncoated tomatoes exhibited a steeper decline, reaching similar firmness levels (approximately 15 N) earlier during storage.

These findings align with those of Hossain et al., (2020) [32], who reported that prolonged storage results in a continuous reduction in fruit firmness. This decrease in firmness is attributed to ongoing metabolic processes, including heightened respiratory and transpiration rates. The activity of microorganisms and enzymes further accelerates these processes, leading to the breakdown of cellular structure and a subsequent decline in fruit quality. The coatings containing natural biopolymers significantly reduce the rate of firmness loss by maintaining cell wall integrity [28]. These factors collectively contribute to the loss of firmness, ultimately reducing the overall quality of the tomatoes during extended storage periods.

3.4. Moisture Content

During storage, the moisture content of tomatoes increases because of respiration. This aerobic process requires oxygen and produces CO_2 and H_2O as byproducts [33]. The results of the analysis show that the moisture content consistently rises as the fruit transitions from unripe to ripe stages (Figure 5). Generally, tomatoes have a moisture content of 90–95% and a dry matter content of 5–10%. While this high moisture content helps meet daily hydration needs, it also accelerates spoilage, making tomatoes more prone to damage [34].

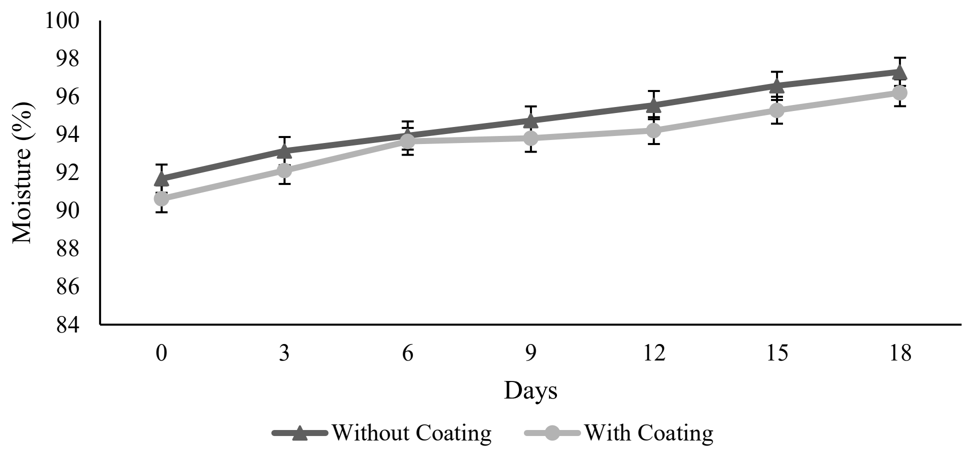

Figure 5. The moisture content of tomato during storage.

The treatments applied significantly influenced the moisture content of tomatoes. Tomatoes without an edible coating experienced faster changes in moisture content compared to those with a coating. This is because the edible coating effectively seals the fruit's pores, reducing respiration and transpiration rates, thereby maintaining its moisture levels for a longer period.

Using regression analysis, the shelf life of tomatoes without an edible coating was determined to be 9.76 days ($R^2 = 0.9986$), while tomatoes with an edible coating had a shelf life of 13.64 days ($R^2 = 0.9497$). These estimations are based on the maximum allowable moisture content of tomatoes, which is set at 95%. The coating acted as a barrier to moisture loss, thereby preserving the fruit's firmness, texture, and appearance over an extended storage period [35].

3.5. Vitamin C

When comparing tomatoes with and without edible coating, the vitamin C content is better preserved in tomatoes with the edible coating, as shown in Figure 6. However, the amount of vitamin C retained in tomatoes decreases over the storage period. This decline is attributed to the activity of the enzyme ascorbate oxidase, which converts vitamin C into dehydroascorbic acid and hydrogen peroxide (H_2O_2) during storage. As a result, there is a risk of autooxidation, which not only degrades the vitamin C content but also affects the color quality of the tomatoes [36].

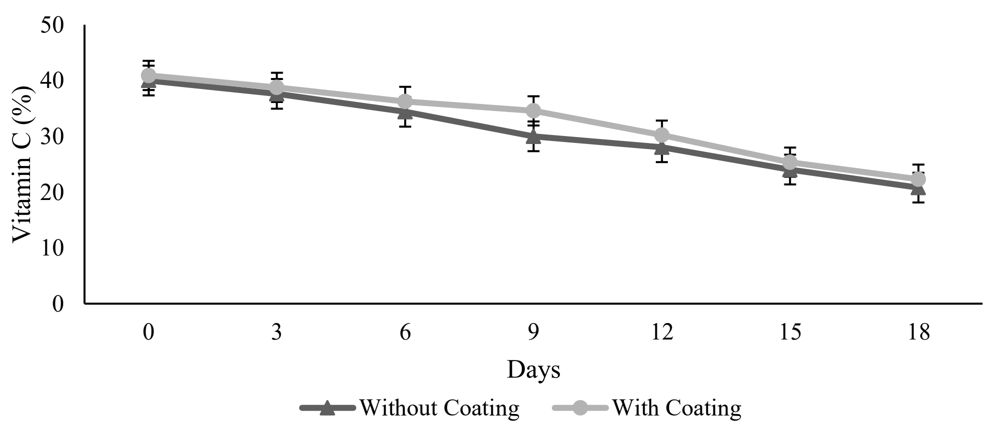

Figure 6. Vitamin C of tomato during storage.

Additionally, edible coatings help maintain the structural integrity of the fruit, reducing the effects of mechanical damage and microbial contamination, both of which contribute to the degradation of vitamin C. By preserving the physical and biochemical stability of tomatoes, edible coatings significantly extend shelf life and maintain nutritional quality during storage. These findings highlight the critical role of edible coatings in mitigating vitamin C loss and maintaining the overall quality of tomatoes during extended storage periods.

3.6. Organoleptic

The organoleptic test result can be seen in Table 1. The application of edible coatings on tomatoes improved their appeal to panelists in terms of color, as the coating enhanced the fruit's glossiness. However, as the storage duration increased, the panelists' preference for the color of the tomatoes gradually decreased. Panelists also favored the texture of tomatoes with edible coatings, as they maintained a firmer texture compared to uncoated tomatoes. Nevertheless, as the storage period progressed and the texture of the tomatoes softened, panelist preference diminished, with a significant decline observed by day 18. Despite this, tomatoes with edible coatings consistently received higher texture ratings compared to those without coatings.

Table 1. Result of the organoleptic test.

Sample	Color	Texture	Aroma	Taste
Without coating	4.61	4.53	4.60	4.46
With coating	4.73	4.59	4.75	4.51

Panelists' preference for the aroma of the tomatoes also decreased over time, particularly for uncoated tomatoes, which were less favored as the storage period advanced. Tomatoes with edible coatings were generally preferred in terms of aroma due to their ability to maintain freshness for a longer duration.

In terms of taste, tomatoes with edible coatings were more appealing to panelists, as the coating contributed a subtle sweetness derived from glycerol. However, as the storage period lengthened, the panelists' preference for the taste of the tomatoes, regardless of coating, gradually declined. Overall, the use of edible coatings enhanced the sensory qualities of tomatoes, making them more desirable to panelists across various attributes, particularly during the early stages of storage.

4. CONCLUSION

The application of potato starch-based edible coatings significantly improved the postharvest quality of tomatoes. Coated tomatoes exhibited lower weight loss, better firmness retention, slower color degradation, and enhanced moisture and vitamin C retention compared to uncoated tomatoes. The coating's ability to reduce respiration, transpiration, and microbial activity contributed to its effectiveness in extending the shelf life of tomatoes to approximately 13.64 days, compared to 9.76 days for uncoated samples. Sensory evaluations confirmed that coated tomatoes were more appealing in terms of color, texture, and taste, particularly during the early stages of storage. These findings highlight the effectiveness of potato starch-based edible coatings as an eco-friendly and practical solution for preserving the quality and extending the shelf life of tomatoes.

AUTHOR CONTRIBUTION

All authors contributed equally to the main contributor to this paper. All authors read and approved the final paper. **Mohammad Prasanto Bimantio**: Writing (review & editing), writing (original draft), investigation, formal analysis. **Astri Wulandari**: Writing (review & editing), writing (original draft), formal analysis. **Ida Bagus Banyuro Partha**: Investigation, writing (review & editing), supervision, conceptualization, funding acquisition.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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