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Effects of Cassava-Starch Coating Concentration on the Postharvest Quality of Tomato (*Solanum lycopersicum* L.)

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ABSTRACT

This study evaluated 0%, 2%, 4%, and 6% cassava-starch coatings for maintaining Mustafi tomato quality during 10 days of ambient storage. A completely randomized design with six replications per treatment was used. Coated fruit showed lower weight loss, greater firmness, lower total soluble solids, and higher vitamin C than uncoated fruit. Colour and texture category scores and carotenoid development varied with concentration. The 2% treatment provided a compromise between preservation and red-colour development; however, this selection requires a prespecified decision criterion. Complete reporting of control formulation, repeated-measures analysis, analytical methods, and the carotenoid observation date is required before independent reproduction.

Keywords: tomatoes, edible coating, cassava starch, postharvest quality, storage

INTRODUCTION

Tomato is an important horticultural commodity belonging to the Solanaceae family and is cultivated extensively in Indonesia, particularly in Java, North Sumatra, and several parts of Sulawesi. Data published in the 2024 Horticulture Statistics report show that national tomato production reached 1,152,791 metric tons, exceeding the figure recorded in the preceding year. This production level reflects the importance of tomatoes as both a food crop and a source of economic value. Tomatoes also provide several compounds that are beneficial to human health, including vitamin C, lycopene, carotenoids, minerals, sugars, organic acids, and volatile constituents that contribute to flavour and aroma. Their vitamin C and lycopene contents make tomatoes a widely consumed source of natural antioxidants and a valuable raw material for the food industry (Zhang *et al*., 2023).

Despite their nutritional and economic value, tomatoes have a relatively short postharvest life. As climacteric fruit, they contain approximately 93% water and continue to respire and transpire after harvest. These physiological processes gradually reduce water and vitamin C contents, alter fruit colour, and soften the tissue during

storage (Pratiwi *et al*., 2024). Consequently, tomatoes stored at ambient temperature without appropriate postharvest treatment tend to deteriorate rapidly and have a limited shelf life.

Applying an edible coating is one possible means of limiting postharvest deterioration. This consumable layer is produced from natural materials and forms a thin barrier over the fruit surface, thereby restricting respiration and transpiration. By moderating these processes, an edible coating can help retain fruit freshness, texture, and nutritional quality during storage (Novita and Suyatma, 2022; Pratiwi *et al*., 2024). Cassava starch is particularly suitable as a coating material because it is readily obtainable, inexpensive, biodegradable, non-toxic, and capable of producing a transparent film (Novita and Suyatma, 2022).

Previous findings support the use of cassava starch coatings for preserving tomato quality. Adjouman *et al*. (2018) found that modified cassava starch coatings delayed changes in firmness, colour, and total soluble solids relative to uncoated fruit. Yudiyanti and Matsjeh (2020) further reported that coatings derived from cassava peel starch helped retain total phenolic compounds and vitamin C. Similarly, Putra (2022b) demonstrated that cassava starch coatings could maintain tomato colour and texture and, consequently, prolong storage life.

Accordingly, this study examined the effects of cassava starch (Manihot esculenta Crantz) edible coatings on the physical and chemical quality of tomatoes (Solanum lycopersicum L.) during storage and sought to determine the most suitable coating concentration.

MATERIALS AND METHODS

Time and Location of the Study

The study was conducted between November 2025 and June 2026, covering material preparation, experimental work, and data analysis. All laboratory procedures were undertaken at the Postharvest Laboratory, Faculty of Agriculture, Swadaya Gunung Jati University, Cirebon. During storage, room temperature ranged from 25.9 to 28.3 °C, while relative humidity remained between 50% and 60%.

Research Materials and Equipment

The materials comprised Mustafi tomatoes, cassava starch, distilled water, glycerol, carboxymethyl cellulose (CMC), potassium sorbate, tapioca flour, starch indicator, and iodine solution. The instruments included beakers, Erlenmeyer flasks, spatulas, a blender, sieve, thermometer, volumetric flask, burette, Bunsen burner, tripod, pipettes, knife, mortar and pestle, funnel, UV–Vis spectrophotometer, digital refractometer, filter cloth, digital balance, fruit firmness tester, bucket, tray, and stationery.

Experimental Design

A single-factor completely randomized design (CRD) was employed, with cassava starch concentration as the experimental factor. Four coating treatments were evaluated: P0 (0%), P1 (2%), P2 (4%), and P3 (6%). Tomatoes were immersed in the respective solutions for 60 s and subsequently air-dried at room temperature for approximately 24 h. Each treatment was replicated six times, giving 24 experimental units. Ten tomatoes were assigned to each unit; therefore, 240 tomatoes, weighing approximately 15 kg in total, were used.

Sample Collection

Mustafi tomatoes (Solanum lycopersicum L.) were obtained directly from growers in Sangiang Village, Banjaran Subdistrict, Majalengka Regency. Grade A fruit showing no visible symptoms of pest attack or disease and having a green surface

with an orange tinge were selected. Before treatment, the tomatoes were rinsed with clean water to remove adhering soil and other debris and were then allowed to dry at room temperature.

Preparation of Cassava Starch *(Manihot esculenta Crantz)*

Cassava starch was prepared by adapting the procedure of Putra (2022a) to the red-skinned cassava tubers used in the present study. Preparation was carried out at the researcher's residence in Setu Kulon Village, Weru Subdistrict, Cirebon Regency. The tubers were purchased from Caplek Market, Bode Lor Village, Plumbon Subdistrict, Cirebon Regency.

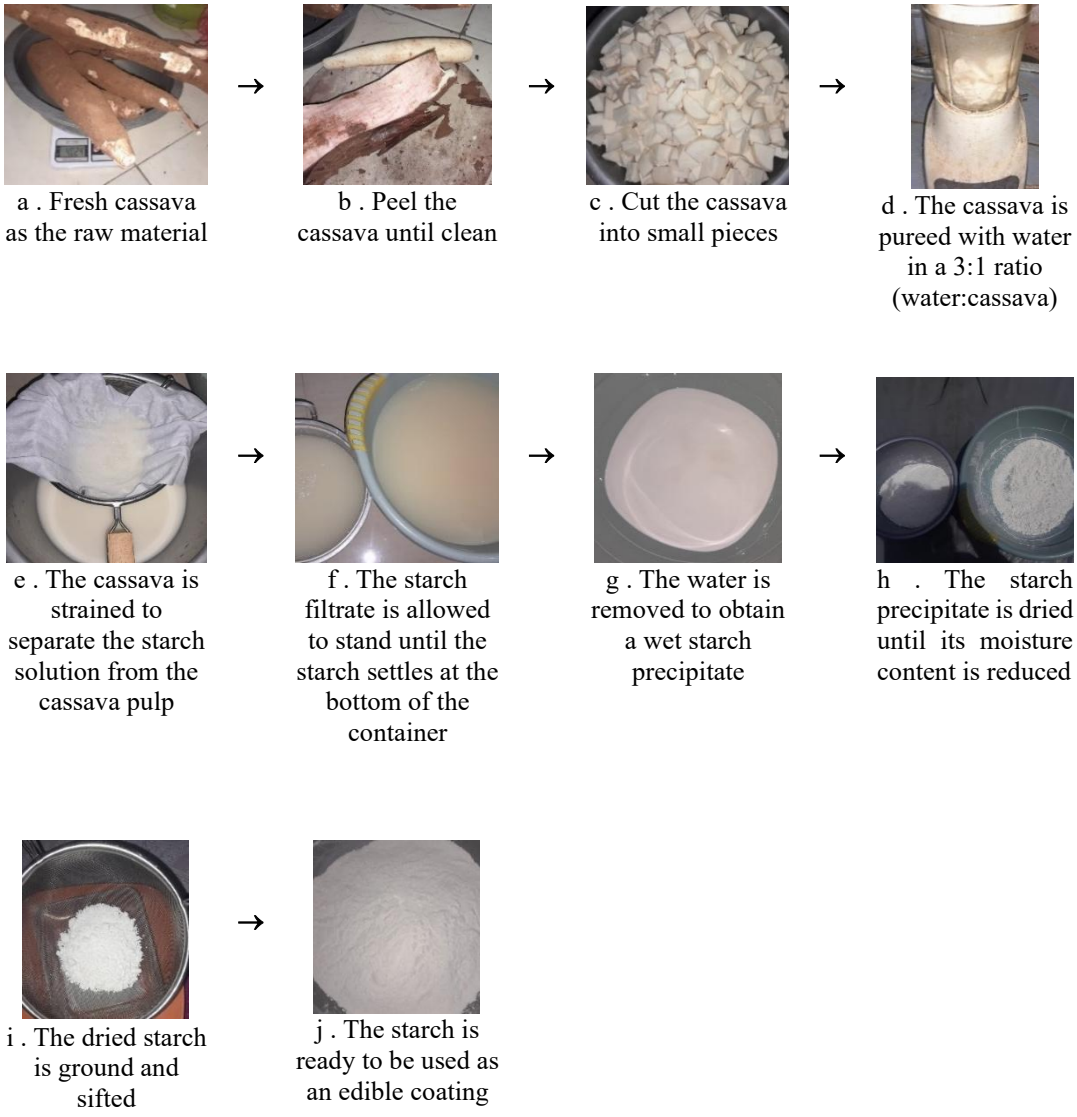


Figure 1. Cassava starch production process

Preparation for making cassava starch *(Manihot esculenta Crantz)* edible coating

The coating formulation was adapted from Putra (2022a), with cassava starch used as the principal film-forming material. The glycerol level and addition of potassium sorbate followed the procedure of Dehya (2015), as cited by Kusuma and Prastowo (2018). Coating solutions were prepared at the Postharvest Laboratory, Faculty of Agriculture, Swadaya Gunung Jati University, Cirebon. The preparation stages are presented in Figure 2.

Sample Treatment

Tomatoes were immersed for 60 s in coating solutions containing 0%, 2%, 4%, or 6% cassava starch. They were then left to dry at room temperature for approximately 24 h, or until the coating had formed a dry layer. The treated fruit were arranged in open trays on a wooden laboratory table and stored for 10 days. Storage took place at the Postharvest Laboratory, Faculty of Agriculture, Swadaya Gunung Jati University, Cirebon, under ambient conditions of 25.9–28.3 °C and 50–60% relative humidity.

Observation Parameters

Weight Loss (%)

Tomato weight was recorded with a digital balance on storage days 1, 5, and 10. Weight before storage was defined as the initial weight (w_0), whereas the value obtained at a given observation time was denoted by w_t. Percentage weight loss was calculated from the reduction in weight relative to the initial value using the following equation:

$$\textbf{Weight Loss} = \frac{\boldsymbol{W0 - Wt}}{\boldsymbol{W0}} \boldsymbol{x}\ \mathbf{100\%}$$

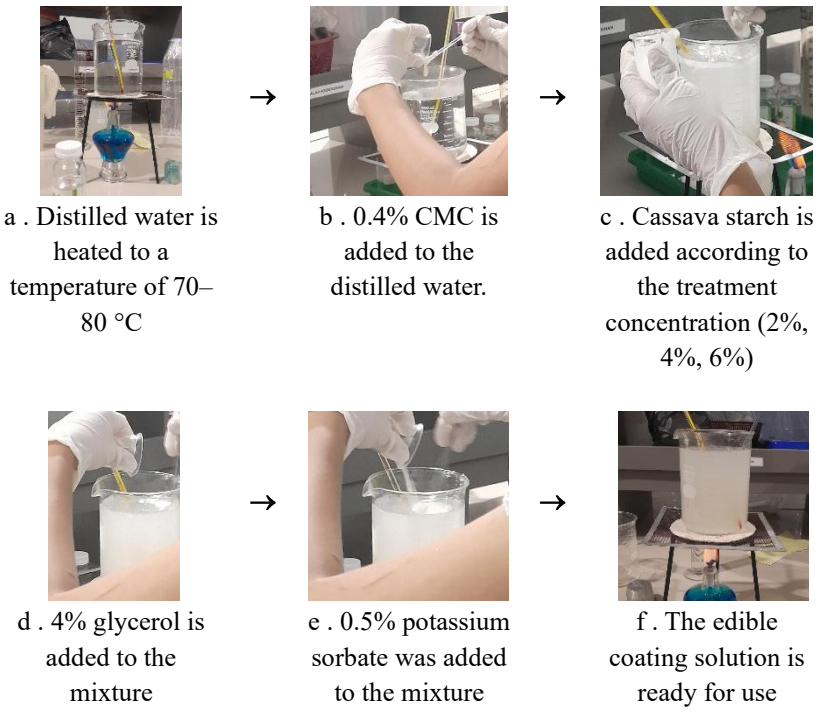


Figure 2. The process of making an edible cassava starch coating

Firmness (kg/cm²)

Fruit firmness was measured on days 1, 5, and 10 using a penetrometer fitted with a fruit probe and calibrated before use. The probe was pressed perpendicularly into the tomato until the maximum reading was displayed. Measurements were taken at the upper, middle, and lower portions of each fruit to reduce sampling error. After every sample, the probe was cleaned and the instrument was reset to zero. Firmness was expressed from the maximum force (Fmax) recorded at each point.

Total Soluble Solids (°Brix)

Total soluble solids were determined on days 1, 5, and 10 with a digital refractometer covering a range of 0–60 °Brix. Tomatoes representing each treatment were crushed, and the juice was collected. Several drops were applied to the cleaned refractometer prism, after which the displayed result was recorded as °Brix.

Vitamin C (mg/100 g)

Tomato vitamin C content was quantified by iodometric titration using 0.01 N iodine (I_2) as the titrant and starch solution as the endpoint indicator. The indicator was prepared by dispersing 2 g of tapioca starch in 100 mL of distilled water until a uniform solution was obtained. Samples were collected from every treatment and replication specified in the experimental design.

After washing, each tomato was cut into small pieces and any damaged tissue was discarded. A known mass of sample was weighed on a digital balance, ground in a mortar with a small volume of distilled water, and diluted to 100 mL. The mixture was filtered, and a 10 mL aliquot was transferred by pipette into a clean Erlenmeyer flask. Starch indicator was added before titration with 0.01 N iodine. The appearance of a persistent blue colour was taken as the titration endpoint. Analyses were performed on storage days 2 and 10, and vitamin C content was calculated according to Ulfatimah *et al*. (2023) using the following equation:

$$\boldsymbol{Vitamin\ C\ (mg/100g)\ =\ \frac{VI_2 \times KI \times FP}{m} \times 100}$$

Carotenoids (mg/g)

A UV–Vis spectrophotometer was used to quantify carotenoids and monitor changes in tomato pigments, particularly lycopene, during storage. Measurements were carried out on days 2 and 10.

Sensory Evaluation

Texture

Sensory assessment was performed on day 6 to examine whether the cassava starch coating could retain tomato quality as perceived by consumers. Ten untrained male and female panellists aged 20 years or older participated, provided that they had no reported visual or taste impairments. Each panellist evaluated the specified attributes using the scoring scale provided. Texture was judged from the consistency of the flesh during consumption. Because tomato tissue normally softens as storage progresses, the coating was expected to delay this change and retain a firmer texture.

Colour

Color was evaluated first because it is immediately apparent and commonly serves as an indication of tomato freshness and maturity. Fruit with a bright and uniform appearance is generally more acceptable to consumers. The cassava starch coating was therefore assessed for its ability to delay colour development during storage.

Data Analysis

Organoleptic scores were summarized descriptively using their median values. All other response variables were subjected to analysis of variance (ANOVA). Where a significant treatment effect was detected, Duncan's Multiple Range Test (DMRT) was applied at $\alpha = 0.05$ to establish differences among treatment means. Statistical calculations were conducted with IBM SPSS Statistics.

RESULTS AND DISCUSSION

Weight Loss

As shown in Table 1, tomatoes in every treatment lost progressively more weight between the first and tenth day of storage. Weight loss on day 1 remained low, ranging from 0.15% to 0.18%, and did not differ significantly among treatments. By day 10, P3 (6%) recorded the smallest loss at 3.16%, followed by P2 (4%) at 3.24% and P1 (2%) at 3.33%. The uncoated control, P0 (0%), showed the greatest loss at 4.46%. Thus, storage duration was accompanied by a gradual increase in tomato weight loss.

The limited weight reduction observed early in storage indicates that respiration and transpiration had not yet caused substantial moisture loss. As storage continued, however, weight loss rose in all groups, with the uncoated control (P0) reaching the highest value of 4.46%. Postharvest weight reduction in tomatoes is mainly associated with water lost through transpiration and with carbon reserves consumed during respiration (Sogvar *et al*., 2016, as cited in Bimantio *et al*., 2025).

Cassava starch forms a semipermeable film on the fruit surface that restricts transpiration and consequently slows moisture loss (Bimantio *et al*., 2025; Kusuma and Prastowo, 2018). At the end of storage, P1, P2, and P3 differed significantly from the uncoated control, suggesting that even the lowest coating concentration provided an effective barrier. The downward pattern in weight loss as concentration increased may reflect the formation of a denser coating layer (Kusuma and Prastowo, 2018; Picauly and Tetelepta, 2019). Kusuma and Prastowo (2018) reported a comparable response in strawberries, in which thicker cassava starch coatings reduced water-related weight loss. The present results therefore indicate that higher cassava starch concentrations can improve moisture retention in tomatoes during ambient storage.

Table 1. Effect of cassava starch edible coating on weight loss

Treatment	Weight Loss (%)	Weight Loss (%)	Weight Loss (%)
	Day 1	Day 5	Day 10
P0 (0%)	0.18 a	2.77 b	4.46 b
P1 (2%)	0.18 a	2.11 a	3.33 a
P2 (4%)	0.16 a	1.98 a	3.24 a
P3 (6%)	0.15 a	1.71 a	3.16 a

Note: Mean values followed by the same letter in the same column indicate no significant difference based on *Duncan's Multiple Range Test* (DMRT) at a 5% significance level ($\alpha = 0.05$).

Firmness Level

Table 2 shows a decline in tomato firmness in every treatment as storage progressed. Initial values ranged from 2.30 to 2.35 kg/cm² and were statistically comparable. Firmness continued to decrease on days 5 and 10, although the reduction was less pronounced in coated fruit. On day 10, P3 (6%) retained the highest firmness at 2.09 kg/cm², whereas P0 (0%) had the lowest value at 1.89 kg/cm².

The observed reduction in firmness is a normal consequence of ripening and indicates progressive quality deterioration. During storage, structural compounds in the cell wall, especially pectin, are broken down and the tissue becomes softer (Duguma, 2022). Continued respiration after harvest activates enzymes involved in the degradation of cell-wall polysaccharides, while transpiration contributes to the loss of cellular turgor (Johannes *et al*., 2022; Tetelepta *et al*., 2019).

Firmness values for P1, P2, and P3 differed significantly from those of P0, indicating that the coating delayed tissue softening. By restricting oxygen movement into the fruit and modifying the gas composition close to its surface, the coating may suppress the activity of enzymes responsible for cell-wall degradation. As a result, the loss of firmness proceeds more gradually (Tetelepta *et al*., 2019). Duguma (2022) likewise reported that coated tomatoes retained firmness values as much as 23% above those of untreated fruit. These observations confirm the capacity of cassava starch coatings to preserve tomato texture during storage.

Table 2. Effect of cassava starch edible coating on hardness levels

Treatment	Firmness (kg/cm², N)	Firmness (kg/cm², N)	Firmness (kg/cm², N)
	Day 1	Day 5	Day 10
P0 (0%)	2.30 a	1.98 a	1.89 a
P1 (2%)	2.33 a	2.13 ab	2.03 b
P2 (4%)	2.31 a	2.16 b	2.05 b
P3 (6%)	2.35 a	2.10 ab	2.09 b

Note: Mean values followed by the same letter in the same column indicate no significant difference based on *the Duncan Multiple Range Test* (DMRT) at a 5% significance level (α = 0.05).

Total Soluble Solids

Total soluble solids (TSS) increased during storage in all treatments. On day 1, values ranged from 3.16 to 3.58 °Brix and did not differ significantly. Differences became more apparent as storage progressed. At day 10, the control treatment, P0 (0%), produced the highest value of 4.41 °Brix, whereas P3 (6%) had the lowest value of 3.33 °Brix. This pattern indicates that increasing the coating concentration moderated the rise in soluble solids (Table 3).

The increase in TSS during storage may be attributed to both moisture loss and biochemical changes associated with ripening. In climacteric fruit, starch is enzymatically hydrolysed into simpler sugars as respiration intensifies, leading to a higher refractometer reading (Paramita *et al*., 2026). A coating can moderate this change by

limiting gas exchange and lowering the respiration rate. Slower respiration delays ripening and reduces the rate at which reserve carbohydrates are converted into soluble sugars (Kusuma and Prastowo, 2018).

At the final observation, all coated treatments had lower TSS values than the control. This result suggests that starch-to-sugar conversion proceeded more slowly in coated tomatoes, consistent with delayed ripening. The difference is plausibly associated with the barrier created by the coating, which limits respiration and thereby slows sugar formation (Paramita *et al*., 2026). Kusuma and Prastowo (2018) described a similar response following the application of cassava starch coating, although their work involved a different fruit. Taken together, these findings support the view that edible coatings can moderate physiological changes governing soluble-solids accumulation during storage.

Vitamin C

Tomato vitamin C content increased over the observation period. On day 2, values ranged from 5.12 to 5.55 mg/100 g and did not differ significantly. Significant variation was evident by day 10: P0 (0%) contained 12.47 mg/100 g, whereas P3 (6%) recorded the highest concentration of 15.28 mg/100 g (Table 4).

Table 3. Effect of cassava starch edible coating on total soluble solids

Treatment	Total Soluble Solids (°Brix)	Total Soluble Solids (°Brix)	Total Soluble Solids (°Brix)
	Day 1	Day 5	Day 10
P0 (0%)	3.58 a	3.91 b	4.41 b
P1 (2%)	3.33 a	3.41 a	3.50 a
P2 (4%)	3.50 a	3.58 ab	3.66 a
P3 (6%)	3.16 a	3.25 a	3.33 a

Note: Mean values followed by the same letter in the same column indicate no significant difference based on the Duncan Multiple Range Test (DMRT) at a 5% significance level (α = 0.05).

Table 4. Effect of cassava starch edible coating on vitamin C

Treatment	Vitamin C (mg/100 g)	
	Day 2	Day 10
P0 (0%)	5.49 a	12.47 a
P1 (2%)	5.55 a	13.78 ab
P2 (4%)	5.36 a	14.85 bc
P3 (6%)	5.12 a	15.28 c

Note: Mean values followed by the same letter in the same column indicate no significant difference based on *the Duncan Multiple Range Test* (DMRT) at a 5% significance level (α = 0.05).

The rise in vitamin C probably reflects the continued ripening of the tomatoes during the 10-day storage period. Ascorbic acid may accumulate while the fruit remains in an active ripening phase, together with other antioxidant compounds produced through ripening-related metabolism. At the same time, the coating can reduce the fruit's exposure to oxygen and limit oxidative degradation of vitamin C (Bimantio *et al*., 2025). Yudiyanti and Matsjeh (2020) similarly observed an initial increase in vitamin C in coated tomatoes until day 6, followed by a decline during prolonged storage. Such a later decline has been associated with ascorbic acid oxidation and advancing tissue deterioration.

The higher values recorded for P2 (4%) and P3 (6%) indicate that these coatings were more effective than the control in retaining vitamin C. This response may represent a balance between ascorbic acid synthesis during ripening and reduced oxidation under the protective film (Bimantio *et al*., 2025). Pratiwi *et al*. (2024) also found that edible coatings contributed to vitamin C retention in stored fruit. Therefore, cassava starch coatings appear capable of limiting nutritional deterioration during storage.

Carotenoids

Carotenoid concentration rose between days 2 and 10 in every treatment. Initial values ranged from 0.0010 to 0.0015 mg/g. By day 10, P1 (2%) produced the highest concentration, at 0.0261 mg/g, while P3 (6%) recorded the lowest, at 0.0146 mg/g (Table 5).

The increase in carotenoids is closely related to lycopene synthesis during tomato ripening. Lycopene is the principal carotenoid responsible for the red appearance of ripe tomatoes, although its concentration may later decline as the fruit enters senescence (Duguma, 2022). As ripening proceeds, chlorophyll is degraded and lycopene is synthesized rapidly, causing the surface colour to shift from green towards red. This pigment transition represents a normal physiological stage in stored tomatoes (Abebe *et al*., 2017).

By limiting gas exchange and respiration, edible coatings may delay ripening and alter the rate of lycopene accumulation. Consequently, pigment development in coated fruit can proceed more slowly than in untreated tomatoes. A comparable delay in lycopene development after coating application was reported by Kibar and Sabir (2018).

Among the coated groups, P1 (2%) retained the highest carotenoid concentration, suggesting that this level provided sufficient protection without excessively restricting normal ripening. In contrast, the lower carotenoid value in P3 (6%) corresponded with its lower organoleptic colour score. The relatively thick barrier produced at 6% may therefore have delayed pigment synthesis more strongly. A moderate concentration appears better able to balance postharvest protection with desirable colour development.

Table 5. Effect of cassava starch edible coating on carotenoids

Treatment	Carotenoids (mg/g)	
	Day 2	Day 20
P0 (0%)	0.0015 a	0.0213 ab
P1 (2%)	0.0013 a	0.0261 b
P2 (4%)	0.0013 a	0.0205 ab
P3 (6%)	0.0010 a	0.0146 a

Note: Mean values followed by the same letter in the same column indicate no significant difference based on *Duncan's Multiple Range Test* (DMRT) at a 5% significance level ($\alpha = 0.05$).

Sensory Evaluation

Organoleptic evaluation uses human senses to describe product quality and consumer acceptance. In the present study, the panel results showed that cassava starch concentration influenced the perceived texture and colour of the tomatoes (Table 6).

Texture

Table 6 indicates that coating application influenced panel acceptance of tomato texture. Median scores ranged from 2 to 3. The three coated treatments, P1, P2, and P3, each obtained a median score of 3, whereas the control treatment received a median score of 2.

The higher texture scores of coated tomatoes indicate that panellists considered them firmer and more acceptable than the control. Coatings at 2%, 4%, and 6% apparently limited moisture loss and helped retain tissue structure, although they also tended to delay ripening. This interpretation is consistent with the role of the coating as a barrier to water movement from the fruit surface (Buendía-Moreno *et al*., 2019, as cited in Duguma, 2022).

The polysaccharide film also functions as a semipermeable barrier to gases, thereby reducing respiration and transpiration. Restricted gas exchange can slow the activation of cell-wall-degrading enzymes, including enzymes involved in pectin breakdown, and thus delay tissue softening (Johannes *et al*., 2022).

Colour

The color assessment results in Table 6 also varied according to coating concentration. Median scores ranged between 2 and 3. P0 (0%) and P1 (2%) achieved a median of 3, while P2 (4%) and P3 (6%) each received a median of 2.

Under the rating criteria, a score of 3 represented a uniformly red surface and a score of 2 represented a yellowish-red appearance. The scores recorded for P0 and P1 indicate more advanced and uniform red-colour development. This change occurs as carotenoid pigments, particularly lycopene, accumulate during ripening (Duguma, 2022). The lower scores obtained by the higher coating concentrations suggest slower pigment development, most likely because the coating reduced respiration and metabolic activity (Kibar and Sabir, 2018).

Tomatoes coated with 4% and 6% cassava starch remained in the yellowish-red category. A thicker film may have restricted gas exchange sufficiently to delay lycopene formation. Conversely, the 2% treatment developed a more acceptable red colour, indicating that ripening could continue without losing the protective benefit of the coating (Abebe *et al*., 2017). This interpretation is supported by the carotenoid results, in which P1 also produced the highest value. Thus, a moderate coating concentration may offer a more favourable balance between preservation and pigment development.

Table 6. Descriptive analysis based on median values for texture organoleptics according to the assessments of untrained panelists

Treatment	Texture	Color
P0 (0%)	2	3
P1 (2%)	3	3
P2 (4%)	3	2
P3 (6%)	3	2

Note: The organoleptic aspect of texture was rated on a 1–3 scale (1 = very soft; 2 = soft; 3 = somewhat hard), while the organoleptic aspect of color was rated on a 1–3 scale (1 = greenish red; 2 = yellowish red; 3 = uniform red).

CONCLUSION

Cassava-starch coatings affected the postharvest quality of Mustafi tomatoes during 10 days of ambient storage. Coated fruit generally lost less weight, retained greater firmness and vitamin C, and showed slower changes in soluble solids than uncoated fruit. Higher concentrations provided stronger preservation for several measures, whereas 2% showed more advanced red-colour and carotenoid development. A single optimal concentration cannot be established without a prespecified composite criterion. Commercial use requires verification of the control formulation, decay and microbial safety, sensory acceptance, coating composition, and economic feasibility.

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