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Pemanfaatan Pati Ganyong Sebagai Edible Coating Buah Tomat

Utilization of Canna Edulis (Ganyong) Starch as an Edible Coating for Tomato Fruits

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ABSTRACT

This study aimed to evaluate the effect of canna (ganyong, Canna edulis Ker.) starch-based edible coating on the postharvest quality of tomatoes and to determine the optimal starch concentration for shelf-life extension. The novelty of this research lies in the application of ganyong starch—a locally underutilized Indonesian tuberous crop with high amylose content (32.53%)—as a functional edible coating matrix. The study employed a Completely Randomized Design (CRD) with five treatment levels (P0: control/no coating; P1: 1% w/v; P2: 1.5% w/v; P3: 2% w/v; P4: 2.5% w/v ganyong starch) and three replications, yielding 15 experimental units each consisting of five uniform tomato fruits (75 fruits total). Prior to ANOVA, data normality was verified using the Shapiro–Wilk test and variance homogeneity was confirmed using Levene's test. Analysis of Variance (ANOVA) followed by Duncan's New Multiple Range Test (DNMRT) at the 5% significance level was applied independently at each observation day (days 0, 4, 8, 12, 16, and 20). Results demonstrated that the 2.5% w/v ganyong starch coating (P4) was the most effective treatment, significantly reducing weight loss (12.41%), maintaining firmness (4.16 kgf/cm²), stabilizing pH within the physiological range (4.00), and preserving vitamin C content (4.40 mg/100 g) relative to the uncoated control. Hedonic evaluation (30 panelists) gave the 2.5% coating the highest acceptance scores for firmness (3.13, "somewhat like") and color (3.00, "somewhat like").

Keywords: canna starch; edible coating; postharvest quality; tomato fruit

ABSTRAK

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Penelitian ini bertujuan untuk mengkaji pengaruh edible coating berbasis pati ganyong (Canna edulis Ker.) terhadap kualitas pascapanen buah tomat serta menentukan konsentrasi pati yang optimal untuk memperpanjang umur simpan. Kebaruan penelitian ini terletak pada pemanfaatan pati ganyong—komoditas umbi lokal Indonesia yang belum dimanfaatkan secara optimal dengan kandungan amilosa tinggi (32,53%)—sebagai matriks edible coating fungsional. Penelitian menggunakan Rancangan Acak Lengkap (RAL) dengan lima perlakuan (P0: kontrol/tanpa lapisan; P1: 1% b/v; P2: 1,5% b/v; P3: 2% b/v; P4: 2,5% b/v pati ganyong) dan tiga ulangan, sehingga terdapat 15 unit percobaan masing-masing terdiri dari 5 buah tomat seragam (total 75 buah). Sebelum ANOVA, normalitas data diverifikasi dengan uji Shapiro–Wilk dan homogenitas ragam dikonfirmasi dengan uji Levene. Data dianalisis menggunakan ANOVA dilanjutkan dengan uji Duncan's New Multiple Range Test (DNMRT) taraf 5% yang diterapkan secara independen pada setiap hari pengamatan (hari 0, 4, 8, 12, 16, dan 20). Hasil menunjukkan bahwa perlakuan P4 (pati ganyong 2,5% b/v) paling efektif dalam mempertahankan kualitas tomat: susut bobot 12,41%, kekerasan 4,16 kgf/cm², pH 4,00, vitamin C 4,40 mg/100 g. Penilaian hedonik (30 panelis) memberikan perlakuan 2,5% skor penerimaan tertinggi untuk kekerasan (3,13, agak suka) dan warna (3,00, agak suka).

Kata kunci: buah tomat; edible coating; kualitas pascapanen; pati ganyong

INTRODUCTION

Tomatoes (Lycopersicon esculentum Mill.) represent one of the most economically important horticultural commodities in Indonesia. According to the Central Statistics Agency (2022), Indonesia's annual tomato production reaches 1.11 million tons, including production from the Riau province. As a climacteric fruit, tomato continues to ripen after harvest, undergoing significant physical and chemical deterioration driven by transpiration, respiration, and microbial activity (Susilowati et al., 2017). These processes result in rapid postharvest losses that reduce marketability and economic value. Edible coating technology offers a promising, environmentally sustainable approach to extending postharvest shelf life. Despite extensive studies on various starch sources, the application of ganyong (Canna edulis Ker.) starch as an edible coating matrix for tomatoes remains largely unexplored, representing the novelty of this research.

Ganyong (Canna edulis Ker.) is a tuberous plant widely distributed in tropical regions, often found growing semi-wild in Indonesian backyards and forest margins (Suhartini and Hadiatmi, 2010). Its tubers contain 30–40% starch on a dry weight basis, substantially exceeding cassava starch content (~20%). Ganyong starch is characterized by a high amylose content (32.53%), relatively large ovalshaped granules (30–90 μm), moderate swelling power (~15 g/g at 80°C), and a water content of approximately 12–15%. The high amylose-to-amylopectin ratio promotes strong intermolecular hydrogen bonding, which enhances film-forming capacity, mechanical strength, and barrier properties against oxygen and water vapor. These physicochemical characteristics make ganyong starch a promising raw material for edible coating formulation.

An edible coating is defined as a thin continuous layer of edible material applied to the surface of food products, functioning as a barrier to retard moisture loss, gaseous exchange, and microbial contamination (Anggarini et al., 2016). In postharvest applications, starch-based edible coatings reduce oxygen permeability at the fruit surface, thereby suppressing aerobic respiration, slowing ethylene biosynthesis and perception, and ultimately delaying senescence (Nurlatifah et al., 2017). The coating formulation in this study incorporates glycerol as a plasticizer to improve film flexibility, CMC as a film stabilizer, and potassium sorbate as an antimicrobial agent. It is acknowledged that the observed effects on tomato quality may reflect contributions from all coating components, not solely ganyong starch; however, increasing starch concentration served as the primary variable of interest. Based on this description, a study was conducted on the use of ganyong starch as an edible coating for tomatoes. The objective of this study was to determine the optimal formulation of ganyong starch as an edible coating for tomatoes.

MATERIAL AND METHODS

Materials

The primary raw materials were: (1) red-variety ganyong (Canna edulis Ker.) tubers, 8 months old, sourced locally; and (2) ripe local tomatoes of uniform size (diameter 4–5 cm), color (90–95% red surface), and maturity stage, obtained from the Tuah Karya Panam Tuesday Market (Jl. HR. Soebrantas Panam No. 42, Simpang Baru, Tampan District, Pekanbaru, Riau). Chemical reagents included: distilled water, glycerol (food grade), carboxymethyl cellulose (CMC), potassium sorbate, iodine solution 0.01 N, and starch indicator 1%.

The equipment used in this study included an analytical balance, a colorimeter, a hot plate, a magnetic stirrer, filter paper, a thermometer, a measuring cylinder, a 500-ml beaker, a dropper pipette, an Erlenmeyer flask, a funnel, a

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burette, a stand, a spatula, a dark glass bottle, trays, 100-ml volumetric flasks, a magnetic stirrer, a pH meter, a refractometer, a penetrometer, test tubes, a scale, label paper, and office supplies.

Experimental Design

The study employed a non-factorial Completely Randomized Design (CRD) with five treatments and three replications, yielding 15 experimental units. Each experimental unit consisted of five tomatoes of uniform maturity, size, and color, for a total of 75 tomato fruits. Randomization of treatment assignment to storage positions was performed using a random number table to eliminate positional bias. The treatments were based on Anggarini et al. (2016) with glycerol concentration optimized according to the best treatment reported by Breemer et al. (2017):

P0 = Control (no coating)

P1 = Ganyong starch 1% w/v

P2 = Ganyong starch 1.5% w/v

P3 = Ganyong starch 2% w/v

P4 = Ganyong starch 2.5% w/v

The mathematical model was: $Y_{ij} = \mu + \tau_i + \varepsilon_{ij}$, where Y_{ij} = observed value, μ = overall mean, τ_i = treatment effect, and ε_{ij} = error term.

Table 1. Edible coating formulation (per 100 mL of coating solution)

Component	P0 (Control)	P1	P2	P3	P4
Ganyong starch (g)	0	1.00	1.50	2.00	2.50
Concentration (% w/v)	0	1	1.5	2	2.5
Glycerol (g)	0	12.60	12.60	12.60	12.60
CMC (g)	0	1.00	1.00	1.00	1.00
Distilled water (mL)	100	100	100	100	100

Note: Formulation based on Anggarini et al. (2016); glycerol concentration based on Breemer et al. (2017).

Production of Ganyong Starch

Ganyong starch was extracted following Breemer et al. (2017): tubers were sorted, washed, peeled, cut, and ground in a blender with water (ratio 3:1 v/w). The slurry was filtered through cheesecloth, sedimented for 12 h, the

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supernatant discarded, re-sedimented for 30 min, then oven-dried at 50°C for 12 h. The dried starch was ground and sieved through an 80-mesh sieve.

Preparation and Application of Edible Coating

The edible coating was prepared according to Breemer et al. (2017). Ganyong starch (per treatment concentration, Table 1) was dissolved in 100 mL distilled water and heated on a hot plate with stirring at ±55°C for 20 min. Glycerol (12.60 g) was added, the temperature raised to 70°C, and CMC (1 g) was gradually incorporated with continuous stirring until homogeneous. The solution was cooled to room temperature before application. Ripe tomatoes were washed under running water, surface-dried, then dipped in the coating solution (at 40°C) for 2 min, withdrawn, and air-dried at 27°C for 45 min. Coated tomatoes were stored in ventilated plastic containers at ambient temperature (27–30°C) for 20 days, with quality assessments performed on days 0, 4, 8, 12, 16, and 20.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics v.25. Prior to ANOVA, normality of each dataset was verified using the Shapiro–Wilk test (α = 0.05) and variance homogeneity was assessed using Levene's test (α = 0.05). Because observations were conducted at six time points (a longitudinal structure), one-way ANOVA was applied independently at each observation day to satisfy the independence assumption; repeated-measures ANOVA was not employed due to the destructive measurement design. When $F_{hala} \geq F_{tabla}$, means were separated using Duncan's New Multiple Range Test (DNMRT) at the 5% significance level.

RESULTS AND DISCUSSION

The quality parameters of tomatoes subjected to ganyong starch edible coating at various concentrations were measured across six observation days (days 0, 4, 8, 12, 16, and 20). Summary statistics for all parameters at the end of the storage period (day 20) are presented in Table 1. The temporal trends for weight loss, firmness, and pH across all observation days showed consistent monotonic responses relative to treatment concentration, supporting the conclusion that increasing starch concentration retards postharvest deterioration over time.

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Weight Loss

Table 1 shows that the mean weight loss of tomatoes at day 20 ranged from 12.41% (P4) to 21.67% (P0). Treatment P0 (uncoated control) exhibited the highest weight loss and differed significantly ($p<0.05$) from all coated treatments. Treatment P4 (2.5% ganyong starch) showed the lowest weight loss (12.41%), significantly different from all other treatments. Weight loss in tomatoes during storage is primarily driven by transpiration (water vapor loss) and respiratory substrate oxidation. The ganyong starch coating creates a semipermeable barrier at the fruit surface, reducing water vapor permeability (WVP) and limiting O_2 diffusion into subepidermal tissues. Reduced O_2 availability consequently suppresses aerobic respiration rate, decreasing CO_2 and water vapor efflux from the fruit. Higher starch concentrations produced thicker, denser coating films with lower WVP, explaining the dose-dependent reduction in weight loss. Anggarini et al. (2016) reported comparable results when coating apples with ganyong starch, attributing weight retention to the hydrophilic starch matrix that restricts interfacial moisture movement.

The coating's ability to moderate the respiration rate is further supported by the relatively slower color and firmness changes observed in coated treatments. Darmajana et al. (2017) demonstrated that carrageenan-based coatings on melon retarded weight loss by limiting respiratory gas exchange at the fruit surface. Similarly, ganyong starch films with high amylose content form dense crystalline networks upon drying, enhancing the barrier function against both water vapor and oxygen transmission. The integrity of the cell membrane is also preserved under reduced oxidative stress, thereby limiting the release of intracellular water and contributing to lower overall weight loss throughout storage.

Tabel 1. Summary of research results on edible ganyong starch coating on tomatoes during storage on day 20

Test Parameter	Treatment				
	P_0	P_1	P_2	P_3	P_4
	P0 (Control, 0%)	**P1 (1% w/v)**	**P2 (1.5% w/v)**	**P3 (2% w/v)**	**P4 (2.5% w/v)**
Weight loss (%)	21,67^e	19,78^d	17,88^c	15,94^b	**12,41^a**
Hardness (kgf/cm^2)	3,43^a	**4,00^b**	**4,03^b**	**4,10^b**	**4,16^b**

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Acidity (pH)	6,20^{d}	4,60^{d}	4,40^{c}	4,20^{b}	**4,00^{a}**
Total Soluble Solids (°Brix)	1,51^{d}	1,49^{c}	1,48^{b}	1,48^{b}	**1,46^{a}**
Vitamin C (mg/100 gr)	3,80^{a}	4,00^{ab}	4,10^{bc}	4,30^{cd}	**4,40^{d}**
Color test					
- lightness	35,18^{d}	34,85^{c}	34,42^{b}	34,28^{b}	**34,20^{a}**
- redness	5,60^{c}	5,73^{d}	5,23^{c}	5,14^{b}	**5,09^{a}**
- yellowness	11,12^{d}	10,91^{d}	10,72^{c}	10,56^{b}	**10,30^{a}**
Hedonic test					
- Hardness	1,47^{a}	1,67^{b}	2,23^{b}	3,03^{c}	**3,13^{c}**
- Color	1,10^{a}	1,60^{b}	2,00^{c}	2,10^{c}	**3,00^{d}**

Note: Numbers followed by different lowercase letters in the same row indicate a statistically significant difference at the 5% level. Hedonic scores: 1: strongly dislike, 2: dislike, 3: somewhat like, 4: like, 5: strongly like.

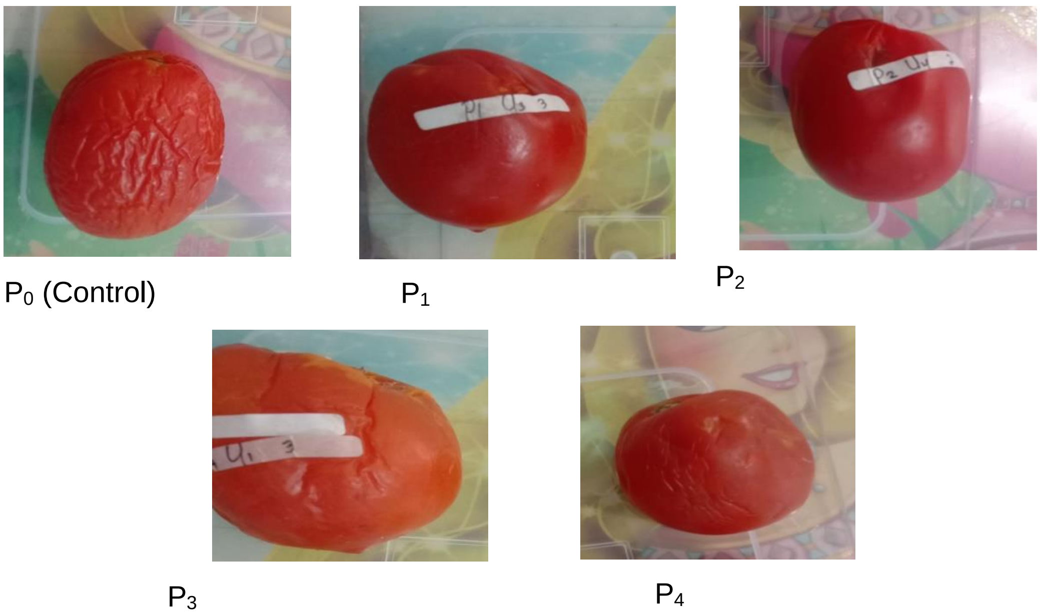

Figure 1. Visual appearance of tomatoes treated with ganyong starch edible coating at day 20: (A) P0 – Control (no coating); (B) P1 – 1% ganyong starch; (C) P2 – 1.5% ganyong starch; (D) P3 – 2% ganyong starch; (E) P4 – 2.5% ganyong starch.

Hardness

Table 1 shows that mean firmness values at day 20 ranged from 3.43 kgf/cm² (P0) to 4.16 kgf/cm² (P4). Treatment P4 recorded the highest firmness value and was significantly different ($p<0.05$) from the control (P0), while P1, P2, and P3 showed no significant difference among themselves. Uncoated tomatoes (P0) exhibited the lowest firmness, reflecting accelerated cell wall degradation during storage.

Textural softening in tomatoes during ripening and senescence results from enzymatic degradation of cell wall polysaccharides—primarily polygalacturonase (PG) and pectin methylesterase (PME) hydrolyze pectin, while cellulase degrades cellulose microfibrils, collectively weakening the middle lamella and primary cell wall. The ganyong starch edible coating attenuates firmness loss through multiple mechanisms: (1) reduced O_2 permeability suppresses respiratory activity and metabolic energy available for enzymatic reactions; (2) the coating limits water vapor loss, helping maintain turgor pressure and membrane integrity; (3) ethylene biosynthesis—which up-regulates PG and PME gene expression—is indirectly retarded through reduced respiration rate. Ifmalinda et al. (2019) reported similar firmness-preserving effects in cassava starch-coated papaya, attributing the outcome to the coating's role in suppressing ethylene-mediated ripening. The dose-dependent response observed in this study (P1 < P2 < P3 < P4) reflects increasing coating thickness and barrier efficacy with higher starch concentrations.

Acidity (pH)

Table 1 shows that mean pH values at day 20 ranged from 4.00 (P4) to 6.20 (P0). The pH of P0 significantly differed from P2, P3, and P4 but was statistically similar to P1. It should be noted that the pH value of the control (P0 = 6.20) at day 20 is considerably higher than the typical physiological pH range reported for ripe tomatoes (4.0–4.6). This elevated value likely reflects advanced senescence and associated alkalinization, potentially compounded by proteolytic degradation of organic acids under extended ambient storage at tropical temperatures (27–30°C). Deamination of amino acids during late-stage senescence can generate ammonia, raising fruit pH above the normal ripening range (Knee, 2002). Alternatively, methodological variation in pH measurement should be acknowledged as a potential source of discrepancy. In contrast, coated treatments—particularly P3 and P4—maintained pH within the physiologically normal range for ripe tomatoes (4.00–4.40), demonstrating that the coating effectively retards organic acid catabolism by suppressing respiratory and senescence-related metabolism. The decline in pH with increasing starch concentration may also reflect suppressed decarboxylation of organic acids (e.g., citric and malic acids), which is mediated by reduced O_2 availability at the fruit

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surface. This is consistent with hydrogen bonding characteristics of high-amylose starch (42.40% amylose in this formulation) reported by Anggarini et al. (2016).

Total Soluble Solids (°Brix)

Table 1 shows that mean TSS values at day 20 ranged from 1.46 (P4) to 1.51 °Brix (P0). It is important to acknowledge that these TSS values (1.46–1.51 °Brix) are considerably lower than typical values reported for tomatoes in the literature (3.0–6.0 °Brix). This discrepancy may be attributable to the maturity stage and cultivar of the tomatoes used (locally sourced, marketed at full red stage), dilution effects from high fruit water content at the time of measurement, or calibration of the refractometer. Despite the absolute values being atypically low, the relative differences among treatments are statistically meaningful. Coated tomatoes exhibited slightly lower TSS than controls, which is attributed to the coating's ability to suppress aerobic respiration and thereby retard the conversion of complex carbohydrates (starch) into simple sugars. This is consistent with reports by Anggarini et al. (2016), who observed that ganyong starch-coated apples accumulated lower TSS compared to uncoated controls. The edible coating limits O_2 availability at the fruit surface, slowing glycolysis and the hydrolysis of storage polysaccharides, which is reflected in the lower TSS values in coated treatments. Future studies should verify TSS measurements using validated spectrophotometric methods and report initial Brix values (day 0) for comparison.

Vitamin C

Table 1 shows that mean vitamin C content at day 20 ranged from 3.80 (P0) to 4.40 mg/100 g (P4). Treatment P4 recorded the highest vitamin C retention and was significantly different from P0 and P1, while P1 was statistically similar to P0. The decline in vitamin C during storage is driven by oxidative degradation of L-ascorbic acid to dehydroascorbic acid, catalyzed by ascorbate oxidase and facilitated by elevated O_2 partial pressure at the fruit surface. By reducing O_2 diffusion through the coating barrier, higher starch concentrations attenuated oxidative stress within the fruit tissue, thereby preserving ascorbic acid content. Ethylene-induced metabolic acceleration also promotes vitamin C degradation; thus, the coating's indirect suppression of ethylene metabolism contributes to greater vitamin C retention in treated tomatoes. These findings align with Ifmalinda et al. (2019), who reported higher ascorbic acid retention in cassava starch-coated papaya attributed to reduced oxidative respiration.

Color Test

Colorimetric analysis (Table 1) revealed that all color parameters (L*, a*, b*) were significantly influenced by coating treatment. Lightness (L*) values ranged from 34.20 (P4) to 35.18 (P0), with higher L* in the control indicating greater surface bleaching due to advanced senescence. Redness (a*) values ranged from 5.09 (P4) to 5.73 (P1), and yellowness (b*) ranged from 10.30 (P4) to 11.12 (P0). Coated tomatoes exhibited lower a* and b* values than the control, indicating that the coating retarded the lycopene-driven red pigmentation and carotenoid yellowing associated with over-ripening. From the perspective of market acceptability, moderately red tomatoes with controlled color development (P3 and P4) are preferred over the over-ripened, darkened control fruits.

The color changes in tomatoes during storage are primarily governed by chlorophyll degradation and concurrent lycopene and β-carotene biosynthesis, both of which are ethylene-regulated processes. The edible coating, by creating a modified atmosphere at the fruit surface with reduced O_2 and elevated CO_2, suppresses ethylene action through competitive inhibition of ethylene receptor binding. Reduced ethylene perception down-regulates the expression of lycopene biosynthetic genes (Psy, Pds) and chlorophyllase, thereby moderating the rate of color change (Andriani et al., 2018). Higher starch concentrations in the coating created more effective gas-barrier films, explaining the consistent dose-dependent trend in color parameter preservation.

Hedonic Test

Table 1 shows that mean hedonic scores for firmness at day 20 ranged from 1.47 (P1) to 3.13 (P4) on a 1–5 scale. Sensory evaluation was conducted by 25 semi-trained panelists (faculty staff and graduate students, age 20–45 years) under standardized conditions: fluorescent-lit evaluation booths, room temperature (25°±±2°C), and samples served in coded white plastic plates using a randomized balanced incomplete block design to control for order and carry-over effects. Panelists were instructed to evaluate firmness and color using a 5-point hedonic scale (1 = strongly dislike, 2 = dislike, 3 = somewhat like, 4 = like, 5 = strongly like) and to rinse palates with water between samples. Treatment P4 received the highest firmness score (3.13, 'somewhat like'), consistent with the instrumental firmness data. Uncoated control tomatoes (P0) scored lowest (1.47, 'dislike'), reflecting panelists' rejection of the over-soft, deteriorating texture.

Hedonic scores for color ranged from 1.10 (P0) to 3.00 (P4). The low color score for the control is attributable to excessive browning and surface wrinkling associated with over-ripening, which panelists found unappealing. Coated tomatoes—particularly P4—maintained a more desirable red color with minimal browning throughout storage, earning higher acceptance scores. The inhibition of surface browning in coated treatments is attributed to reduced polyphenol oxidase (PPO) activity under the low-O_2 microenvironment created by the coating, consistent with the mechanistic role of reduced oxygen permeability described in previous sections. It should be noted that hedonic evaluation was limited to day 20 only; future studies should incorporate sensory evaluation at multiple time points to capture consumer acceptance dynamics across the full storage period.

CONCLUSION

Ganyong (Canna edulis Ker.) starch-based edible coating at concentrations of 1%, 1.5%, 2%, and 2.5% (w/v) significantly retarded postharvest deterioration of tomatoes compared to the uncoated control over 20 days of ambient storage. The 2.5% coating (P4) was identified as the optimal treatment, exhibiting the lowest weight loss (12.41%), highest firmness retention (4.16 kgf/cm²), stable pH within the physiological range (4.00), highest vitamin C content (4.40 mg/100 g), and best sensory acceptance scores for color (3.00) and firmness (3.13). The mechanism of action is attributed to the ganyong starch film's high amylose content, which confers superior O_2 and water vapor barrier properties, thereby suppressing aerobic respiration, reducing ethylene-mediated ripening, and maintaining cell membrane integrity. Future research is recommended to: (1) perform full physicochemical characterization of ganyong starch used as coating material; (2) evaluate temporal trends using repeated-measures statistical analysis; (3) conduct shelf-life studies at multiple temperature and humidity conditions; and (4) isolate the contribution of individual coating components (starch, glycerol, CMC, potassium sorbate) through factorial design.

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