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

Fenna Firlianty[1], Dodi Budirokhman[2*]

[1]Agrotechnology Program, Faculty of Agriculture, Swadaya Gunung Jati University, Cirebon, Jl. Pemuda Raya No. 32, Kesambi District, Cirebon City, West Java, **Indonesia**
[2]Faculty of Agriculture, Swadaya Gunung Jati University, Cirebon, Jl. Pemuda Raya No. 32, Kesambi District, Cirebon City, West Java, **Indonesia**

[*]*Corresponding author:* dodibudirokhman@ugj.ac.id

ABSTRACT

Tomato fruit is highly perishable because respiration and transpiration continue after harvest. This study evaluated chitosan coatings at six concentrations for maintaining the quality of Mustafi tomatoes (Solanum lycopersicum L.) during eight days of ambient storage. A completely randomized design comprised 0% (uncoated control), 1%, 2%, 3%, 4%, and 5% chitosan, with four biological replications per treatment. Weight loss, firmness, total soluble solids, vitamin C, and carotenoid content were evaluated. Treatment means differed significantly for several quality attributes. The 1% coating produced the lowest weight loss and retained comparatively high firmness and vitamin C. Higher concentrations did not consistently improve preservation. Under the tested conditions, 1% chitosan provided the most balanced overall response; however, coating composition, repeated-measures analysis, and analytical protocols require complete reporting before the formulation can be independently reproduced.

Keywords: chitosan, edible coating, fruit quality, postharvest, tomato

INTRODUCTION

Tomato (Solanum lycopersicum L.) is an economically important horticultural commodity in Indonesia. Production is concentrated mainly in Java, followed by North Sumatra and several areas of Sulawesi. Statistics issued by the Directorate General of Horticulture show that national tomato production reached 1,152,791 t in 2024, exceeding the output recorded in the preceding year (Ministry of Agriculture, Directorate General of Horticulture, 2024). The scale and continued growth of production reflect strong market demand; however, these benefits may be constrained by substantial postharvest losses.

Tomatoes remain metabolically active after separation from the plant. Respiration consumes stored substrates, while transpiration removes water from the tissue; together, these processes accelerate ripening, alter nutritional composition, and shorten marketable life. Their high moisture content also makes tomatoes vulnerable to mechanical injury and microbial deterioration during handling, distribution, and storage. Appropriate postharvest management is

therefore required to preserve quality and extend shelf life (Asjulia, 2022).

A short storage life is a persistent challenge for tomato producers because part of the harvested crop may deteriorate before reaching consumers. Typical symptoms include mass loss, tissue softening, changes in chemical attributes, and microbial decay, all of which reduce product value and may cause economic losses. The use of suitable postharvest technology is consequently important for maintaining tomato quality throughout storage (Fitriani *et al*., 2022).

One approach is the application of an edible coating, a thin consumable film formed directly on the commodity surface. The film moderates the transfer of water vapor, respiratory gases, and dissolved compounds between the fruit and its surroundings. By partially limiting these exchanges, edible coatings can reduce moisture loss and respiration, help retain tissue hydration, and prolong the useful life of horticultural produce (Surip *et al*., 2022).

Chitosan is a hydrocolloid widely investigated as an edible-coating material because it combines film-forming capacity with antimicrobial activity. Its interaction with microbial cell membranes can impair membrane integrity and inhibit spoilage organisms, including fungi and both Gram-positive and Gram-negative bacteria (Maghfiroh *et al*., 2018). Earlier studies reported that chitosan coatings reduced tomato weight loss relative to uncoated fruit (Nur *et al*., 2019) and helped preserve firmness and total soluble solids during storage (Sari *et al*., 2021). Nevertheless, coating performance may vary with concentration because film thickness influences permeability to gases and water vapor. Accordingly, this study examined the effects of several chitosan-based edible-coating concentrations on the postharvest quality of Mustafi tomatoes.

MATERIALS AND METHODS

Study Site and Period

The experiment was conducted in April 2026 at the Postharvest Laboratory, Faculty of Agriculture, Universitas Swadaya Gunung Jati, Cirebon, West Java, Indonesia. Mustafi tomatoes were harvested from a grower in Sangiang Village, Banjaran District, Majalengka Regency.

Materials and Equipment

The experimental materials comprised Mustafi tomatoes, distilled water, shrimp-waste-derived chitosan powder, and 1% acetic acid. Ascorbic acid, iodine solution (I_2), and tapioca starch were used for vitamin C analysis. The principal equipment consisted of basins, an analytical balance, thermometer, stopwatch, penetrometer, hand-held refractometer, thermo-hygrometer, and UV–Vis spectrophotometer.

Experimental Design

A single-factor completely randomized design was used with chitosan concentration at six levels: 0%, 1%, 2%, 3%, 4%, and 5%. Each treatment was replicated four times, resulting in 24 experimental units. Ten tomatoes were assigned to each unit (240 fruit in total) and stored at 25–28 °C and approximately 50% relative humidity. The final submission should state the randomisation procedure, experimental unit used in each analysis, allocation of fruit to destructive tests, sensor accuracy, and environmental logging frequency.

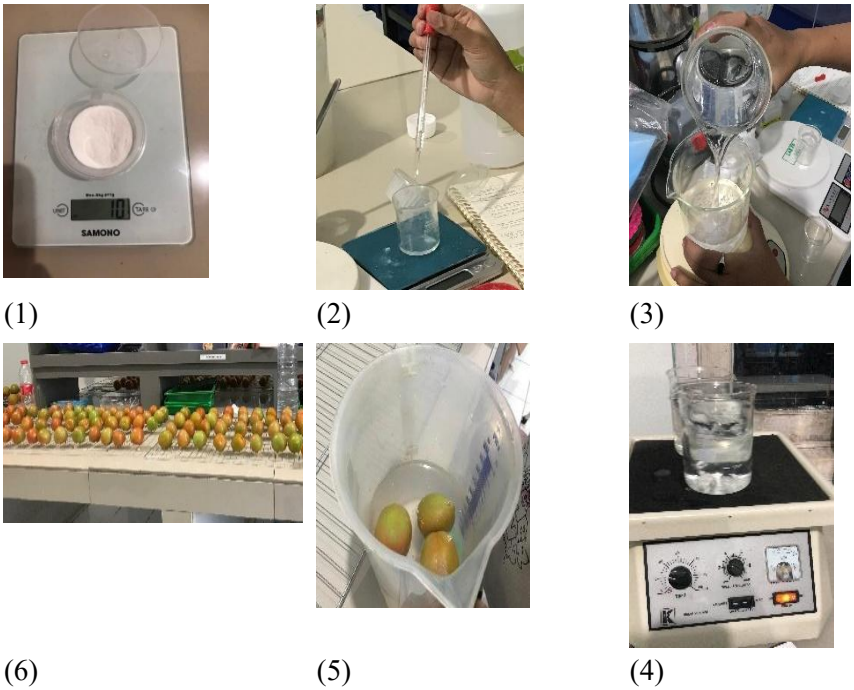
Preparation of Chitosan Coating Solutions

Coating solutions were prepared by adapting Wulandari and Ambarwati (2022). For nominal chitosan concentrations of 1%, 2%, 3%, 4%, and 5% (w/v), respectively, 10, 20, 30, 40, or 50 g of chitosan was dispersed and each solution was brought to a final volume of 1,000 mL. The source procedure

used different volumes of 1% acetic acid across treatments. Before publication, the authors must report the final acetic-acid concentration in every treatment and demonstrate that solvent concentration did not confound the chitosan effect. Solutions were mixed using a VRN-360 shaker until no visible aggregates remained and were then used for dip coating (Figure 1).

Coating Application and Storage

Tomatoes were immersed for 60 s in the assigned coating solution and then air-dried at ambient temperature for approximately 24 h. Samples were placed in open trays and stored for eight days under monitored room conditions. The final submission should specify fruit maturity, sanitation, sample randomisation, coating uptake, drying temperature and relative humidity, and whether day 1 was counted before or after drying (Figure 2).



(1) (2) (3)

(6) (5) (4)

Figure 1. Preparation and application of the chitosan coating solution.



Figure 2. Arrangement of experimental samples

Measured Variables

Weight Loss (%)

Fruit mass was recorded with a digital balance before storage and on days 1, 4, and 7. Weight loss was expressed as the percentage difference between initial mass (Ba) and mass at each observation (Bb), calculated using the following equation:

$$\textbf{Weight Loss} = \frac{\boldsymbol{Ba - Bb}}{\boldsymbol{Ba}} \boldsymbol{x}\ \mathbf{100\%}$$

Notes:
Ba = Weight on day 0 (g)
Bb = Weight on day n (g)

Firmness

Firmness was measured on days 1, 4, and 7 using a penetrometer at the upper, middle, and lower portions of each fruit. The mean of the three readings was used. The instrument model, probe geometry, penetration depth and speed, sample support, calibration, and reporting unit must be specified before submission.

Total Soluble Solids (°Brix)

Total soluble solids were measured on days 1 and 7 using a hand-held refractometer. A representative drop of tomato juice was placed on the prism, and the result was read directly in °Brix. The prism was cleaned and the instrument was checked between samples to minimize carry-over and reading error.

Vitamin C

Vitamin C was determined on days 2 and 8 by iodometric titration with 0.01 N iodine and starch indicator and expressed as mg 100 g^{-1} fresh weight. Technical titrations were performed in triplicate. The final manuscript must define the iodine equivalence constant, sample preparation, dilution factor, endpoint procedure, biological replicate, and complete calculation equation.

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

Notes:
VI_2 = volume of iodine used (mL)
KI= iodine calibration
FP = dilution factor
m = sample mass (g)

Carotenoids

Carotenoid content was measured on days 2 and 8 using UV–Vis spectrophotometry. Before submission, the method must be completed with sample mass, extraction solvent and volume, extraction conditions, wavelength, blank, calibration standard or extinction coefficient, equation, and number of biological and technical replicates.

Data Analysis

For each observation day, data were analysed by analysis of variance for a completely randomized design, followed by Duncan's multiple range test at $\alpha = 0.05$ when the overall treatment effect was significant. The final submission should identify the software and version, assumption tests, transformations, experimental unit, and treatment of repeated measurements over time. Means should be reported with SE or SD and exact P values.

$$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$$

Note:

Y_{ij} = Observations on the i-th treatment of the j-th replication
μ General average
α_i = Influence of the i-th treatment
ε_{ij} = Experimental error for the ith treatment in the jth replication

RESULTS AND DISCUSSION

Weight Loss

Tomato weight loss increased progressively with storage time. Values ranged from 0.23 to 0.44% on day 1, from 0.39 to 1.69% on day 4, and from 0.86 to 2.74% on day 7. This trend reflects the continued loss of water through transpiration and the consumption of stored substrates through respiration after harvest (Table 1).

The uncoated control (K0) consistently showed the greatest weight loss and reached 2.74% on day 7, whereas K1 (1% chitosan) recorded the smallest loss, at 0.86%. The coating presumably formed a semipermeable surface barrier that limited moisture migration and moderated respiration. This interpretation agrees with Wulandari and Ambarwati (2022), who found that chitosan coatings suppressed respiratory activity and water loss in stored tomatoes.

On day 7, K0 belonged to significance group c, K1 to group a, and K2–K5 to group b. Thus, the control lost significantly more mass than every coated treatment, while the 1% coating performed significantly better than the higher concentrations. The absence of a surface barrier in K0 allowed water to escape more readily; coated fruit, by comparison, retained a larger proportion of its initial moisture.

The response was not linearly related to chitosan concentration. Although K1 produced the lowest weight loss, increasing the concentration beyond 1% did not provide additional protection. A denser film at higher concentrations may have altered gas diffusion and reduced the functional effectiveness of the coating. The results therefore identify 1% chitosan as the most effective concentration for limiting tomato weight loss under the conditions of this study (Lupiyanti, 2025).

Table 1. Effect of chitosan-based edible-coating concentration on tomato weight loss during storage

No	Treatment	Weight Loss (%)		
		Day 1	Day 4	Day 7
1	0% (control)	0.44 b	1.69 c	2.74 c
2	1% chitosan	0.23 a	0.39 a	0.86 a
3	2% chitosan	0.32 ab	0.95 b	1.54 b
4	3% chitosan	0.35 ab	1.02 b	1.69 b
5	4% chitosan	0.40 b	1.09 b	1.90 b
6	5% chitosan	0.36 ab	1.19 b	2.03 b

Note: Numbers followed by the same letter in the same column indicate no significant difference based on the DMRT test at the 5% level.

Firmness level

Firmness differed among treatments during storage. On day 1, K1 had the highest mean (2.30 kg cm^{-2}), but it did not differ significantly from K2 or K3. Because treatment differences were already present at the first observation, the authors should determine whether fruit were balanced for baseline maturity and firmness before coating. Firmness generally declined by days 4 and 7 (Table 2).

On day 1, K1–K3 were assigned to group b, whereas K0, K4, and K5 were in group a. On day 4, K1 and K2 retained the greatest firmness (group c), followed by K0 and K3 (group b), while K4 and K5 had the lowest values (group a). By day 7, K1 remained the firmest treatment (group c); K0 and K2 were classified as bc, K3 as b, and K4–K5 as a. The decline observed across storage is consistent with pectin solubilization during ripening. Pectinolytic enzymes convert insoluble protopectin in the cell wall into soluble fractions, thereby weakening tissue structure (Wulandari & Ambarwati, 2022).

The comparatively high firmness of K1 and K2 is consistent with a possible barrier effect at lower chitosan concentrations. Conversely, K4 and K5 produced lower values. Because film thickness and internal O_2 and CO_2 were not measured, explanations involving excessive film thickness or restricted gas diffusion should be treated as hypotheses requiring direct validation.

Table 2. Effect of chitosan-based edible-coating concentration on tomato firmness during storage

No	Treatment	Firmness (kg cm^{-2})					
		Day 1		Day 4		Day 7	
1	0% (control)	1.42	a	1.57	b	1.55	bc
2	1% chitosan	2.30	b	1.95	c	1.77	c
3	2% chitosan	2.20	b	1.80	c	1.65	bc
4	3% chitosan	2.10	b	1.57	b	1.47	b
5	4% chitosan	1.47	a	1.15	a	1.17	a
6	5% chitosan	1.55	a	1.05	a	1.15	a

Note: Means followed by the same letter within a column are not significantly different according to DMRT at the 5% level.

Total Soluble Solids

Total soluble solids (TSS) changed differently among treatments as storage progressed. No significant treatment effect was detected on day 1, whereas significant differences were evident by day 7, indicating that the influence of the coatings developed over time (Table 3).

All treatments were assigned the same significance letter on day 1, demonstrating that coating concentration had not yet produced a measurable difference in TSS. At this early stage, ripening and respiration were likely proceeding at broadly similar rates. On day 7, however, K0 remained in group a while all coated treatments (K1–K5) were in group b. The separation indicates that chitosan application helped modify the pattern of soluble-solids change during storage.

After seven days of storage, the control had the lowest TSS value (3.00 °Brix), whereas coated fruit ranged from 3.75 to 4.00 °Brix and did not differ significantly from one another. Faster respiration in uncoated tomatoes may have increased the use of soluble sugars as metabolic substrates, resulting in the lower final value. The coating acted as a partial barrier to O_2 and CO_2 transfer and therefore likely moderated respiratory metabolism. A higher coating concentration

did not necessarily yield higher TSS: K5 was slightly lower than K4, possibly because a thicker film delayed ripening and, consequently, the conversion of complex carbohydrates into simple sugars (Dhall, 2013).

The preservation of soluble solids is consistent with the barrier properties of chitosan. By reducing the transfer of water vapor and respiratory gases, the film slows changes in sugars and other soluble constituents relative to uncoated fruit. The higher and comparatively stable TSS values in the coated treatments therefore provide additional evidence that chitosan can help maintain tomato chemical quality during storage (Sidik *et al*., 2022).

Table 3. Effect of chitosan-based edible-coating concentration on tomato total soluble solids during storage

NO	Treatment	TSS (°Brix)	
		Day 1	Day 7
1	0% (control)	3.62 a	3.00 a
2	1% chitosan	3.75 a	3.87 b
3	2% chitosan	3.37 a	3.75 b
4	3% chitosan	3.50 a	3.87 b
5	4% chitosan	3.75 a	4.00 b
6	5% chitosan	3.87 a	3.87 b

Note: Means followed by the same letter within a column are not significantly different according to DMRT at the 5% level.

Vitamin C

DMRT group letters were used to interpret differences in vitamin C among treatments. Means sharing at least one letter were not significantly different, whereas means without a common letter differed at the 5% level (Table 4).

After two days of storage, K2 produced the highest vitamin C concentration (7.38 mg 100 g^{-1}) and was assigned to group b, while K0 had the lowest value (4.21 mg 100 g^{-1}; group a). K1 was also in group b, and K3–K5 were classified as ab. On day 8, K1 and K2 contained the most vitamin C and were placed in group c; K3 and K5 were in group bc, K4 in group b, and K0 in group a. Consequently, K1 and K2 differed significantly from the control but not from one another.

Vitamin C increased between the two observation dates in every treatment, which may reflect changes associated with continued ripening. At the same time, chitosan films can limit the exposure of fruit tissue to atmospheric oxygen and thereby slow oxidative loss of ascorbic acid. Similar protective effects of edible coatings on tomato vitamin C have been reported previously (Hizkia Adrie & Andree Wijaya, 2021; Nurma Yunita *et al*., 2025).

K1 and K2 retained more vitamin C than the other treatments, suggesting that coatings at these concentrations provided an effective oxygen barrier without unduly interfering with fruit physiology. Raising the concentration to 4% or 5% conferred no additional benefit. Excessive film thickness may impede gas diffusion to a degree that offsets the desired protective effect. Thus, moderate chitosan concentrations appear more suitable for maintaining nutritional quality (Adiletta *et al*., 2021).

On day 8, K1 had the highest numerical vitamin C concentration (14.03 mg 100 g^{-1}), but it did not differ significantly from K2 or

K3. The result therefore supports a range of effective moderate concentrations rather than an unequivocal advantage of K1 for vitamin C alone. When weight loss and firmness are considered together with vitamin C, K1 provided the most balanced response under the tested conditions.

Table 4. Effect of chitosan-based edible-coating concentration on tomato vitamin C content during storage

No	Treatment	Vitamin C (mg 100 g^{-1})	
		Day 2	Day 8
1	0% (control)	4.21 a	10.35 a
2	1% chitosan	6.92 b	14.03 c
3	2% chitosan	7.38 b	13.70 c
4	3% chitosan	6.11 ab	13.48 bc
5	4% chitosan	4.89 ab	12.06 b
6	5% chitosan	4.92 ab	12.78 bc

Note: Means followed by the same letter within a column are not significantly different according to DMRT at the 5% level.

Carotenoids

For carotenoid content, treatment means sharing a DMRT letter were considered statistically similar, while means with no letter in common differed significantly at $\alpha = 0.05$ (Table 5).

After two days of storage, carotenoid content ranged from 0.001525 to 0.002625 mg 100 g^{-1}. K0 had the lowest numerical value and K5 the highest; nevertheless, all treatments were assigned to group a. Chitosan concentration therefore had no significant effect on carotenoid accumulation at the beginning of storage.

After eight days of storage, the control reached 0.024000 mg 100 g^{-1} and was assigned to group b, whereas coated treatments ranged from 0.014125 to 0.017600 mg 100 g^{-1} and were placed in group a or ab. The higher concentration in K0 indicates more rapid pigment development in uncoated tomatoes. During ripening, chlorophyll is degraded and carotenoid biosynthesis—particularly the formation of lycopene and β-carotene—intensifies, producing the characteristic red color. The lower values in coated fruit suggest that the chitosan barrier moderated respiration and delayed ripening-related pigment accumulation (Duguma, 2022; Kumar & Saini, 2021).

Although K5 had the highest numerical carotenoid value among coated fruit on day 8, it did not differ significantly from K1–K4. The data therefore do not support selecting 5% solely on the basis of carotenoid content. When carotenoid development is considered together with weight loss, firmness, and vitamin C, the 1% treatment offers the most balanced preservation of tomato quality.

Table 5. Effect of chitosan-based edible-coating concentration on tomato carotenoid content during storage

No	Treatment	Carotenoids (mg 100 g^{-1})			
		Day 2		Day 8	
1	0% (control)	0.001525	a	0.024000	b
2	1% chitosan	0.002025	a	0.017600	a
3	2% chitosan	0.002400	a	0.015300	ab
4	3% concentration	0.001800	a	0.014125	ab
5	4% chitosan	0.001825	a	0.015725	a
6	5% chitosan	0.002625	a	0.017250	ab

Note: Means followed by the same letter within a column are not significantly different according to DMRT at the 5% level.

CONCLUSION

Chitosan coatings affected the postharvest quality of Mustafi tomatoes during eight days of ambient storage. The 1% treatment produced the lowest weight loss and retained comparatively high firmness and vitamin C, while coated fruit generally retained more total soluble solids and accumulated carotenoids more slowly than the uncoated control. Concentrations above 1% did not consistently improve preservation. Accordingly, 1% chitosan was the most effective formulation under the specific conditions tested. Broader recommendation requires validation of coating composition, microbial decay, safety, sensory acceptance, and commercial-scale performance.

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