Effect of the edible coating containing cinnamon oil nanoemulsion on storage life and quality of tomato (*Lycopersicum esculentum* Mill) fruits

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**Abstract.** Tomato is one of the fruit vegetables that had perishable properties so that it needs good postharvest handling to increase their shelf life. One of among other technologies, surface coating of tomatoes with edible ingredients added with natural antimicrobials is potential to be applied. Currently, nanotechnology represents an important area and an efficient option for extending the shelf life of foods. The research aimed to investigate the effect of edible coating, containing cinnamon oil nanoemulsion, to extend the storage life and quality of tomato fruits. Treatments given were (a) dipping time in the edible coating formula (1 and 3 minutes), and the storage period of tomatoes, namely 3, 6, 9, 12 and 15 days at room temperature (27°C). As a control treatment, the inspection was also applied on non-coated tomatoes. The results showed that coating treatment was significantly able to delay changes in the quality attributes of tomatoes and longer shelf life compared to fruit that was not coated with an edible coating. Tomato edible coating has better in maintaining physicochemical characteristics (weight loss of 1.83%, TSS 0.34 Brix, vitamin C 59.8 mg/100g and total plate count of 7.88 x 10^6 CFU/g) than control throughout the storage period. The study concludes that cinnamon oil nanoemulsion coating could be a good alternative to preserve the quality and extend the storage life of tomatoes.

1. **Introduction**

Tomatoes are horticulture commodity that susceptible to damage. Up to 30% of the tomatoes are damaged by postharvest handling, mainly caused by pathogenic fungi and bacteria. Tomatoes will shortly have damaged if there are no efforts to overcome the decline, one of them is treated in storage [1]. The edible coating is a technology under consideration as one of the approach methods to improve the shelf-life of the fresh agricultural produce, including tomatoes. The edible coating composed of a renewable material such as lipid mixture, polysaccharide, and protein which act as the barrier of the water vapor, gases, and other solution. It also has functioned as a carrier of a variety of ingredients such as emulsifier, antimicrobials, and antioxidants. Thus, it has the potential to improve quality and extend the shelf life of fresh fruits and vegetables [2].

There is the various technique of applying an edible coating to the product according to [3] which are: dipping, foaming, spraying, casting, brushing and controlled dripping. According to [4] the dipping method is the most widely used method, mainly for vegetables, fruits, meat, and fish. This
method dips the product in the solution which is used as the coating material. This research is applying the edible coating on tomatoes using a dipping method. The edible coating materials used are cornstarch, cinnamon oil nanoemulsion, and glycerol [5]. The cornstarch contains a high compound of amylose about 25%, so it can be used to form the film matrix [6]. The addition of cinnamon oil nanoemulsion has a function as an antimicrobial [7], and glycerol as the plasticizer which can increase the flexibility and extensibility of the polymer [8]. Cinnamon oil nanoemulsion has been able to inhibit the growth of *Staphylococcus aureus* and *Escherichia coli* at 1% (v/v) concentration [7].

The factors used in this research are the long immersion of tomatoes in edible coating solution and storage time. Those factors are expected to affect the shelf-life of the tomatoes. According to [9], the thickness of the edible coating influences the anaerobic respiration to occur and leads to the decay fruits. This research aims to find out the best condition of applying an edible coating on tomatoes, also to examine the effect of long immersion and storage time on the characteristics of tomatoes.

2. Materials and methods

2.1. Materials
The materials used in this research are ripe tomatoes (light red), corn starch, cinnamon oil, tween 80, glycerol, and purified water.

2.2. Experimental design
This research is using Randomized Complete Design (RCD) with 2 (two) factors namely: long immersion (P) and storage time (S). The first factor is long immersion, consists of 2 levels, namely P1 = 1 minute, and P2 = 3 minutes. The second factor that is storage time consists of 5 (five) levels, namely S1 = 3 days, S2 = 6 days, S3 = 9 days, S4 = 12 days and S5 = 15 days.

2.3. Formulation of coarse emulsions and nanoemulsions cinnamon oil
The emulsion system is an oil-in-water (o/w) emulsion with cinnamon oil as the dispersed phase and purified water as the continuous phase. Stages in the making of cinnamon oil nanoemulsion started with the making of the coarse emulsion. The cinnamon oil used is on 20% concentration, and the emulsifier (tween 80) is 15% of the total oil. The mixture of cinnamon oil, tween 80 and purified water then homogenized using High Shear Homogenizer (Ultra-Turrax T25 basic IKA) on homogenization speed of 1000 rpm for 3 minutes to form a coarse emulsion. The next stage is homogenization which using High Pressure Homogenizes (Model GEA Niro Soavi Panda Plus) on 500 bars pressure and three cycles to obtain a nanoemulsion solution [7].

2.4. Formulation of edible coating
The edible coating is made from corn starch with the addition of plasticizer. The plasticizer used is glycerol. The cornstarch is scaled with 3% concentration (w/v of total emulsion). Glycerol is measured with 30% concentration (w/w of corn starch). Corn starch and glycerol are made into suspension with the addition of 100 ml purified water and then heated on 85°C temperature. After that, the suspension is cooled into 45°C [10]. Additions of coarse emulsions and nanoemulsion of cinnamon oil are done after the heating process of the edible coating blend with 1% (v/v of total) concentration. The suspension then the stirred using stirrer to homogenize the solution [11].

2.5. Application of edible coating on tomatoes
Applying an edible coating on tomatoes was conducted using the dipping method. In this method, the tomatoes were dipped in a solution which was used as a coating material. The edible coating solution then was heated on the temperature of ±55°C [12]. After that, the tomatoes were dipped in the coating solution with the duration of dipping for 1 minute and 3 minutes. Then the tomatoes were lifted and drained until the edible coating solution coated the fruit. After that, the fruit was kept in a storage
room for 15 days, and observed daily on the 3, 6, 9, 12, and 15 days.

2.6. Analysis of tomatoes edible coating
Analysis conducted on tomatoes edible coating which covers weight loss (Siburian, 2015), total dissolved solids (Siburian, 2015), and total plate count (SNI 2897:2008).

3. Results and discussion
3.1. Weight loss (%)
The physicochemical characteristics the edible coating of tomatoes analyzed consisted of weight loss, total dissolved solids and vitamin C. Analysis of Variance shows that the long immersion (P) and interaction of long immersion and storage time (PS) has no significant effect (P > 0.05) on the weight loss, total dissolved solid, and vitamin C, while the storage time (S) has a very significant effect (P ≤ 0.01) on the weight loss, total dissolved solids, and vitamin C of tomatoes with edible coating (Table 1).

Table 1. The effect of storage time on the weight loss value, total dissolved solids, and vitamin C of tomatoes without and with edible coating.

| Storage time (days) | Parameter | Weight loss (%) | Total dissolved solids (°Brix) | Vitamin C (mg/100g) |
|--------------------|-----------|-----------------|-------------------------------|---------------------|
| Tomatoes with edible coating |           |                 |                               |                     |
| 3                  |           | 0.12<sup>a</sup> | 0.39<sup>a</sup>              | 337<sup>b</sup>     |
| 6                  |           | 0.73<sup>a</sup> | 0.35<sup>a</sup>              | 342<sup>b</sup>     |
| 9                  |           | 1.31<sup>b</sup> | 0.28<sup>a</sup>              | 337<sup>b</sup>     |
| 12                 |           | 1.88<sup>c</sup> | 0.40<sup>a</sup>              | 440<sup>b</sup>     |
| 15                 |           | 2.37<sup>d</sup> | 0.30<sup>a</sup>              | 440<sup>b</sup>     |
| Tomatoes without edible coating |         |                 |                               |                     |
| 3                  |           | 1.65<sup>a</sup> | 0.30<sup>a</sup>              | 378<sup>d</sup>     |
| 6                  |           | 2.57<sup>d</sup> | 0.38<sup>a</sup>              | 352<sup>c</sup>     |
| 9                  |           | 3.07<sup>c</sup> | 0.40<sup>a</sup>              | 320<sup>b</sup>     |
| 12                 |           | 5.43<sup>f</sup> | 0.40<sup>a</sup>              | 318<sup>b</sup>     |
| 15                 |           | 5.53<sup>f</sup> | 0.50<sup>b</sup>              | 300<sup>a</sup>     |

Note: The different superscript letters in the same column indicate significantly different values (P<0.05).

Weight loss is a parameter that should be known in the preservative process and product shelf-life because of the high decline of weight causes the food product to decompose and decay. The weight loss measurement was conducted to compare the difference between the weight of fruit before and after the storage. The result of the research shows that the percentage of weight loss of tomatoes with an edible coating which observed for 15 days is lower than the percentage of weight loss of tomatoes without edible coating (Table 1), this shows that the presence of a coating layer based on corn starch containing cinnamon oil serves both as a barrier against CO<sub>2</sub>, O<sub>2</sub>, and water which causes respiration and transpiration to be suppressed, so as to maintain fruit quality. Similar results were also revealed by [13] where edible starch-based coatings can inhibit weight loss of the grapevine fruits.

Based on Table 1, the weight loss of edible coating tomatoes tends to increase. The increase of weight loss shows that the loss of weight on tomatoes is getting higher. The increase in weight loss percentage in tomatoes is due to the physiologic process of respiration and transpiration. This increase is expected due to the high respiration rate which continues during storage. According to [14] the process of respiration will produce CO<sub>2</sub>, water, and energy. The energy in the form of heat, water, and
gases produced then will evaporate. The evaporation leads to an increase of weight loss during storage.

According to [15], the layer/film which forms in the surface of fruit acts as a physical barrier to reduce the moisture migration of fruits, also reduces the availability and absorption of oxygen in the fruit to respiration process, hence it will slow the respiration rate and affect the weight loss [16].

The edible coating in this research will cover the tomatoes and minimalize the decline or weight loss. This cover is due to the edible coating materials used are glycerol and starch which provides resistance on transpiration as an inhibitor because those have plasticizers properties. Hence it will protect the tomatoes. Correspondingly with cinnamon oil which has known to contain a bioactive compound that has the capacity as antimicrobial, hence it will be able to inhibit the growth of spoilage microorganism.

3.2. Total dissolved solids (°Brix)

Total dissolved solids (TDS) are an essential factor that needs to be considerate in consumer acceptance. The TDS will increase during the maturity when in the harvest and also during the storage time [17]. The total dissolved solids of edible coating tomatoes obtained ranged from 0.28 - 0.40°Brix with an average value of 0.34°Brix. Meanwhile, the tomatoes without edible coating have TDS value ranged from 0.30 - 0.50 °Brix with the average value of 0.40°Brix (Table 1).

Table 1 shows that TDS of edible coating tomatoes at 15 days was not significantly different from other storage times. Meanwhile, tomatoes without edible coating on 15 days of storage had a TDS of 0.50°Brix, which was significantly different from TDS of edible coating tomatoes for all storage times. This shows that the presence of edible coating can inhibit the increase in TDS when compared to tomatoes without edible coating, namely at 15 days of storage. The edible coating treatment on fruits causes the fruit surface to be protected. Thus, the respiration that triggered on the sugar formation becomes inhibited.

The longer time of the storage leads to the higher content of total dissolved solids. This is related to the respiration rate which the lower respiration rate of the fruit, then the higher content of total dissolved solids obtained. The respiration causes the materials which are a component of total dissolved solids to reduce because it is used as the main material in respiration [18]. The respiration rate would increase at the beginning of storage time and after that In the climacteric fruits, it shows a tendency to decrease along with the length of storage time. Agricultural products, especially ripe tomatoes will have higher total dissolved solids. This increase will be faster if the transpiration occurs rapidly [19].

3.3. Vitamin C (mg/100g)

Vitamin C is a vitamin that is easily damaged during storage. The oxidation processes that occur during the storage lead the vitamin C content to decrease. Besides, the decrease of the vitamin is also caused by vitamin characteristics as the natural water-soluble. The vitamin content in edible coating tomatoes obtained ranged from 337 – 440 mg/100g with an average of 379.2 mg/100g. The result from vitamin C analysis on tomatoes without edible coating obtained ranged from 318 – 378 mg/100g with average 333.6 mg/100g (Table 1).

The result which illustrated in Table 1 shows that the reduction of ascorbic acid during the storage period occurs not only in edible coating tomatoes but also on tomatoes without edible coating. Nevertheless, the decline is higher in tomatoes without edible coating than tomatoes with edible coating. This shows that the coated tomatoes are able to maintain vitamin C levels because it can inhibit the diffusion of O₂ into the fruit tissue [20] which is essential to initiate the respiration process [21]. Similarly, [22] also reported that the chitosan edible coating shows a slower increase of ascorbic acid than the one without coating of peeled litchi fruit. These findings indicate that the coating of chitosan can slow down the synthesis of ascorbic acid during the maturity stage which related to the availability of O₂ for respiration and oxidation. the reduction of O₂ would inhibit the degradation of ascorbic acid to dehydroascorbic acid and H₂O₂. The H₂O₂ obtained will cause an autooxidation and
increase the damage of vitamin C. [3] mentioned that the application of edible coating has potential barrier properties for O₂, CO₂, and lipid.

3.4. Total plate count (CFU/g)
Total plate count analysis was performed using extract of edible coated tomatoes and without edible coat. Total bacteria of edible coated tomatoes obtained ranged from 7.37 x 10⁶ – 7.67 x 10⁶ CFU/g with an average of 7.53 x 10⁶ CFU/g. Moreover, the result from observing the total bacteria of tomatoes which kept without edible coat ranged from 7.71 x 10⁶ – 8.11 x 10⁶ CFU/g with an average 7.88 x 10⁶ CFU/g.

The result from analysis of variance shows that the long immersion (P) has no significant effect (P>0.05) on the total bacteria of edible coating tomatoes, while the storage time (S) has very significant effect (P≤0.01) and interaction between long immersion and storage time (PS) has significant effect (P≤0.01) on the total bacteria of edible coating tomatoes produced. The effect of interaction between long immersion and storage time (PS) on the total bacteria of edible coating tomatoes could be seen in Figure 1.

Figure 1 shows that immersing the tomatoes for 3 minute and 3 days of storage time resulted in the total edible coated tomatoes bacteria with the highest value of 7.67 x 10⁶ CFU/g, but there was not significant different among other treatments. This finding indicates that no bacterial growth occurs on the edible coated tomatoes during the 15 days of storage time.

The research from [23] showed that part of the component in cinnamon bark (Cinnamomum burmannii) has the ability as antibacterial and antioxidant [24]. The cinnamon oil could destroy the bacterial cell membrane, resulting in cell lysis and death, and the cell membrane leading to the loss of nucleic acid in the cell. This implied that cinnamon oil disrupted the membrane and caused subsequent loss of intracellular constituents required to sustain life [25]. Therefore, the microbial growth will be inhibited, and the agricultural product is last longer in the storage.

According to [26], the inhibit power of cinnamon is influenced by antibacterial compounds such as (E)-cinnamaldehyde dan proanthocyanidin. According to [27], the extract of cinnamon bark showed a better antibacterial activity on gram-positive rather than a gram-negative. This difference might be due to the difference of cell wall structure of gram-positive bacteria and gram-negative bacteria. The cell
wall of gram-negative bacteria contains more lipopolysaccharide (LPS), so the lipid content on the bacteria is very high. On the contrary, the cell wall of gram-positive bacteria composed of a stack of peptidoglycan layers and fewer LPS.

4. Conclusions
The result from the research shows that coating the tomatoes with an edible coating with the addition of cinnamon oil nanoemulsion can delay the changes in weight loss value, total dissolved solids, and vitamin C compared without edible coated. Edible coated tomatoes have a better characteristic during 15 days of storage compared to tomatoes without edible coat. The use of cinnamon oil could be a good alternative for preserving the quality and extending the shelf life of fresh tomato fruit.

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References
[1] Peralta-Ruiz Y, Tovar C D G, Sinning-Mangonez A, Coronell E A, Marino M F and Chaves-Lopez C 2020 Reduction of postharvest quality loss and microbiological decay of tomato “chonto” (Solanum lycopersicum L.) using chitosan-E essential oil-based edible coatings under low-temperature storage Polymers (Basel). 12
[2] Lin D and Zhao Y 2007 Innovations in the development and application of edible coatings for fresh and minimally processed fruits and vegetables Compr. Rev. Food Sci. Food Saf. 6 60–75
[3] Krochta J M B E A and N-C M O 1994 Edible coating and film to improve food quality. Technomic Publishing Company New York
[4] R D I G and F O 1994 Edible film and coating characteristics, formation, definition and testing methods. Company Inc. Pennsylvania
[5] Yusnaini R, Ikhsan I, Idroes R, Munawar A A, Arabia T, Saidi N and Nasution R 2021 Near-infrared spectroscopy (NIRS) as an integrated approach for rapid classification and bioactive quality evaluation of intact Feronia limoni IOP Conf. Ser. Earth Environ. Sci. 667
[6] Sandhu K S and Singh N 2007 Some properties of corn starches II: Physicochemical, gelatinization, retrogradation, pasting and gel textural properties Food Chem. 101 1499–507
[7] Aisyah Y, Haryani S, Safrani N and El Husna N 2018 Optimization of emulsification process parameters of cinnamon oil nanoemulsion Int. J. Adv. Sci. Eng. Inf. Technol. 8 2092–8
[8] W W I M dan H D 1993 An introduction on the mechanical properties of solid polymers. Wiley. New York
[9] Rachmawati M 2010 Kajian Sifat Kimia Salak Pondoh (Salacca edulis Reinw) dengan Pelpisan Kitosan Selama Penyimpanan untuk Memprediksi Masa Simpan J. Teknol. Pertan. Univ. Mulawarman 6 20–4
[10] Basyir F, Munawar A A and Aisyah Y 2021 Near infrared reflectance spectroscopy: Classification and rapid prediction of patchouli oil content IOP Conf. Ser. Earth Environ. Sci. 667
[11] Kusumawati D H and Putri W D R 2013 Karakteristik Fisik Dan Kimia Edible Film Pati Jagung Yang Diinkorporasi Dengan Perasan Temu Hitam J. Pangan dan Agroindustri 1 90–100
[12] Huse A M, Wignyanto and Dewi I A 2014 Aplikasi Edible Coating dari Karagenan dan Glicerol untuk Mengurangi Penurunan Kerusakan Apel Romebeauty Fak. Teknol. Pertan. Univ. Brawijaya 1–10
[13] Wahjuningsih S B, Rohadi, Susanti S and Setyanto H Y 2019 The effect of k-carrageenan addition to the characteristics of jicama starch-based edible coating and its potential application on the grapevine Int. J. Adv. Sci. Eng. Inf. Technol. 9 405–10
[14] Wills R, Mc-Glasson B G D and J D 2007 Postharvest, an introduction to the physiology and
handling of fruits, vegetables and ornamentals. 4th ed. UNSW Press

[15] Toğrul H and Arslan N 2004 Extending shelf-life of peach and pear by using CMC from sugar beet pulp cellulose as a hydrophilic polymer in emulsions Food Hydrocoll. 18 215–26

[16] Abbasi N A, Iqbal Z, Maqbool M and Hafiz I A 2009 Postharvest quality of mango (mangifera indica l.) fruit as affected by chitosan coating Pakistan J. Bot. 41 343–57

[17] Tolesa G N and Workneh T S 2017 Influence of storage environment, maturity stage and pre-storage disinfection treatments on tomato fruit quality during winter in KwaZulu-Natal, South Africa J. Food Sci. Technol. 54 3230–42

[18] Crisosto C H, Retzlaff W A, William L E, DeJong T M and Zoffoli J P 2019 Postharvest Performance Evaluation of Plum (Prunus salicina Lindel., ´Casselman´) Fruit Grown under Three Ozone Concentrations J. Am. Soc. Hortic. Sci. 118 497–502

[19] A ] Baldwin E 1999 Edible coatings for fresh fruits and vegetables: past, present and future. Lancaster. Technomic Pub. CO. In

[20] Srinivasa P C, Ramesh M N and Tharanathan R N 2007 Effect of plasticizers and fatty acids on mechanical and permeability characteristics of chitosan films Food Hydrocoll. 21 1113–22

[21] Ayranci E and Tune S 2004 The effect of edible coatings on water and vitamin C loss of apricots (Armeniaca vulgaris Lam.) and green peppers (Capsicum annuum L.) Food Chem. 87 339–42

[22] Dong H, Cheng L, Tan J, Zheng K and Jiang Y 2004 Effects of chitosan coating on quality and shelf life of peeled litchi fruit J. Food Eng. 64 355–8

[23] Izyani A F, Taher M S D 2016 The mode of antimicrobial action of Cinnamomum burmannii´s essential oil and cinnamaldehyde 2 41–7

[24] Ervina M, Nawu Y E and Esar S Y 2016 Comparison of in vitro antioxidant activity of infusion, extract and fractions of Indonesian Cinnamon (Cinnamomum burmannii) bark Int. Food Res. J. 23 1346–50

[25] Cui H Y, Zhou H, Lin L, Zhao C T, Zhang X J, Xiao Z H and Li C Z 2016 Antibacterial activity and mechanism of cinnamon essential oil and its application in milk J. Anim. Plant Sci. 26 532–41

[26] Shan B, Cai Y Z, Brooks J D and Corke H 2007 Antibacterial properties and major bioactive components of cinnamon stick (Cinnamomum burmannii): Activity against foodborne pathogenic bacteria J. Agric. Food Chem. 55 5484–90

[27] Tortora G J F B R and C C 2007 Microbiology an introduction 11 th Edition. Addison Wesley Longman, United States