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The Application of *Aloe vera* Gel as Coating Agent to Maintain the Quality of Tomatoes during Storage

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Abstract: *Aloe vera* is widely used to manufacture medicinal products, cosmetics, and hair treatments. The polysaccharide components in *A. vera* gel can be used as ingredients for edible films or coatings. The edible film can also be applied to fresh fruits and vegetables using the coating principle. Tomatoes are one of the fruit commodities that can be maintained in terms of quality during storage using an edible coating. This study aims to determine the effect of an edible coating made from *A. vera* on tomatoes' physical, chemical, and organoleptic properties during storage. The *A. vera* gel was prepared and used for coating the tomatoes, and the tomatoes were then stored for twelve days. The analysis was conducted every three days, and a comparison with non-coated tomatoes was performed for tomatoes' physicochemical and organoleptic properties. The results show that the application of A. vera as a coating agent could prolong the shelf life of tomatoes, as described in the ability to decrease moisture content and weight loss. The coated tomatoes had lower titratable acidity value, pH, and total soluble solid contents than the non-coated tomatoes. From the organoleptic test, the non-coated tomatoes were preferred by the panelists for color, but the glossiness, skin appearance, and texture of the coated tomatoes were preferred. The coating process could maintain the hardness of tomatoes and prevent the production of phenolic compounds, flavonoids, and lycopene; thus, the antioxidant activity could be conserved.

Keywords: tomato; *Aloe vera*; edible coating; storage; postharvest

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1. Introduction

Aloe vera is a Liliaceae family plant extensively distributed in the Middle East and Africa. This plant is widely grown in tropical and subtropical areas, including Indonesia. Its resistance to dry conditions is because of its ability to absorb and store water for a longer time. Therefore, *A. vera* can live in drought and extreme dry conditions [1]. *A. vera* is widely used to manufacture medicinal products, cosmetics, and hair treatments [2]. Meanwhile, on a small scale, it is also processed for food products such as nata de *A. vera*, drinks, and snack mixes. However, the utilization of *A. vera* is limited to food products because it naturally tastes bitter when consumed [3].

The most significant component of *A. vera* gel is water (99.20%). The remaining solids consist of carbohydrates, monosaccharides comprising mainly glucomannan and small amounts of arabinan and galactan, and polysaccharides such as D-glucose, D-mannose, arabinose, galactose, and xylose [4]. According to Gupta et al. [5], the active chemical components contained in *A. vera* are vitamins, minerals, lignin, saponins, salicylic acid, and amino acids, which could act as antimicrobials and antioxidants.

The presence of polysaccharide components in *A. vera* gel can be used as an ingredient for edible films or coatings. Polysaccharide components can provide hardness, density, quality, viscosity, adhesiveness, and gelling ability [6]. An edible film or coating is a thin layer made of hydrocolloids (proteins, polysaccharides, and alginates), lipids (fatty acids, glycerol, and wax), and emulsifiers that function as coatings of or packaging for food

products and at the same time can be directly consumed [7]. The main goal of developing edible films or coatings is to create an environmentally friendly packaging or protector for food and food products to replace plastic or other harmful substances to extend the product's shelf life. In addition, the advanced research of edible film and coating allows them to become carriers of beneficial compounds such as vitamins, minerals, antioxidants, and antimicrobials. As a result, the film or coating are able to actively protect the food and food products from damage [8]. Moreover, the edible film and coating can also carry preservative agents, flavoring agents, and colorants to extend the shelf life, enhance the flavor, and improve the appearance of food and food products [9]. Some food products that often found using edible packaging are candy, chocolate, sausage, dried fruit, and bakery products [10].

The edible film can also be applied to fresh fruits and vegetables using the coating principle. An enormous percentage of postharvest losses, especially for fruits and vegetables, is a major challenge in developing countries to ensuring food security status [11]. In contrast to edible films that are in a solid layer form when used to wrap food products, edible coatings are applied in a liquid state to coat fruits or vegetables by dipping or spraying. The coating agent will then dry and form a thin layer that protects the product. As a result, the edible coating can extend the shelf life of fresh fruits and vegetables because it decreases the contact with oxygen, as well as the respiration rate, and generally affects the metabolism of fruits and vegetables, thereby preventing the spoilage of fruits [12]. In addition, the presence of an edible coating also inhibits the transpiration of water vapor from the commodity to the environment, reducing the risk of wilting and weight loss and minimizing the vulnerability to insects or other animals, known as postharvest losses [13]. Due to their functionality and environmentally friendly nature, research on edible coatings has been increasing rapidly, especially characterization based on different materials and formulation, for example the use of starch, soy protein isolate, carboxymethyl cellulose, alginate, chitosan, agar, chlorine, ascorbic acid as an antioxidant, pectin, and essential oil coatings, and their application on food and food products, such as strawberries, blueberries, apples, and several types of cut fruit [14].

Tomatoes (*Solanum lycopersicum* Mill.) are one of the fruit commodities that can be maintained in terms of quality during storage using the edible coating. Tomato, as a climacteric fruit, is susceptible to postharvest damage [15]. The skin and flesh of the fruit are soft, increasing the risk of physical damage due to friction and impact. Wounds on the surface of the fruit skin will trigger damage due to the increase in respiration rate and the growth of microbes, thus accelerating spoilage [16]. Proper storage for tomatoes at 10 °C could extend the shelf life by 14 days. Meanwhile, tomatoes which are stored at room temperature (25 °C) undergo a rapid quality decrease on the fifth day of storage [17]. Research on the application of edible coatings on tomatoes has been reported [18–20], generally using various starch and hydrocolloids. However, limited research is available on the edible coatings made from *A. vera* to maintain the physical, chemical, and organoleptic qualities of tomato during storage. Therefore, this study aims to determine the effect of an edible coating made from *A. vera* on tomatoes' physical, chemical, and organoleptic properties during storage.

2. Materials and Methods

A. vera was grown in Madiun District, East Java, and purchased through a national *A. vera* supplier in Sidoarjo District, East Java Province, Indonesia. Meanwhile, the tomatoes were obtained from local farmers in Malang District, East Java Province. The tomatoes (cv. Ratna) were harvested 90 days after sowing in July 2021. A total of 150 tomatoes were selected, 5 tomatoes for each coating and non-coating treatment and for 3 replications. The tomatoes were chosen within the turning level of maturity, which means that more than 10% but not more than 30% of the surface in the aggregate shows a definite change in color from green to tannish-yellow, pink, red, or a combination thereof. The average diameter of the tomatoes was 2.5 ± 0.25 cm, weight 20 ± 2 g for each tomato, and they had

a slightly acidic taste with the absence of injury. Meanwhile, the *A. vera* was harvested at six months (July 2021), possessed a clean green skin color, was approximately 45 ± 4.5 cm long, weighed around 350 ± 35 g for each rind, and had the absence of injury on the surface of the rind. Moreover, the chemicals used for analysis (NaOH, phenolphthalein indicator, H_2SO_4, $FeCl_3$, Folin Ciocalteau, Na_2CO_3, gallic acid, $NaNO_2$, $AlCl_3$, hexane, acetone, ethanol, DPPH, BHT, $FeSO_4.7H_2O$) were purchased from Merck, Darmstadt, Germany, and Sigma Aldrich, Singapore, unless otherwise stated.

2.1. Preparation of A. vera Coating Gel and Coating Process

The *A. vera* rind was washed to remove the impurities. Then, it was trimmed, and the thick outer skin was peeled. Next, the gel fraction was washed with warm water to remove the yellow sap. The gel was then crushed using a blender and filtered through 80 mesh sieves to separate the gel from the solid fraction. The gel was then heated in an iron cast pot using a stove at 80 °C for 5 min. After heating, the *A. vera* gel was allowed to cool to room temperature. Meanwhile, the tomato was washed to remove the impurities, soaked in the *A. vera* gel for 5 min, and placed in an open tray at room temperature to let the *A. vera* gel dry. The coated tomato was then kept in the open space at room temperature for 12 days. The observation was conducted at the interval of 3 days.

2.2. Moisture Content

The thermogravimetric method was used to determine the tomato's moisture content. Briefly, the sample was cut, and 1 g of the sample was put in a weighing bottle. The sample was then placed in the drying oven at 105 °C for 2 h. After that, the sample was cooled in a desiccator for 10 min before weighing. This step was repeated until the constant weight of the sample was achieved. Finally, the sample's moisture content was expressed as the moisture percentage within the sample.

2.3. Weight Loss

The weight loss of the sample was monitored during the storage period. The weight of the tomatoes was measured at the beginning of the experiment (day 0) after the air drying. Then, the sample was weighed every 3 days of observation for 12 days. The weight loss was expressed as a percentage of loss to the initial weight.

2.4. Titratable Acidity

The titratable acidity of tomatoes was measured according to [21]. Briefly, the sample was crushed. Then, 10 g of sample was placed in a 100 mL volumetric flask, filled with distilled water, and mixed thoroughly. After that, the sample solution was filtered using Whatman no. 42 filter paper. Then, 10 mL of sample was placed in an Erlenmeyer flask, and three drops of 1% phenolphthalein indicator were added. Finally, the titration was performed using 0.1 N NaOH until the pale pink color was observed. The result was expressed as a percentage of titratable acidity.

2.5. The pH

The pH was examined using a pH meter. First, 10 mL of tomato filtrate was placed in a glass beaker. Next, the electrode was simmered in the sample until the stable pH value was observed.

2.6. Total Soluble Solid

The total soluble solid of tomato was determined using a refractometer. In brief, three drops of the tomato filtrate were placed in the refractometer prism, which was cleaned beforehand using distilled water and lens paper, and the measurement was performed. The result was expressed as °Brix.

2.7. Color

The color profiles of tomatoes were determined using the color reader Konica Minolta CR-10 (Konica Minolta, Osaka, Japan). The results were expressed as lightness (L*), redness (a*), yellowness (b*), hue (°h), and chroma (C).

2.8. Hardness

The hardness of the tomato was measured using texture profile analyzer equipment (TA-XT Plus, Stable Micro Systems Ltd, Surrey, United Kingdom) [22]. The probe used was a cylindrical probe with a diameter of 36 mm. The hardness of the sample was determined as the highest peak identified from the curve produced by the equipment. The result was expressed as Force (N).

2.9. Organoleptic Test

The organoleptic test was performed to determine sensory properties of tomato preferred by the panelists. The quality parameters tested were color, glossy, skin appearance, texture, and aroma. The scoring methods (1–5 score) were used for all parameters. In this test, the coated and non-coated tomato stored after 9 days was chosen because it reflects the optimum condition of tomatoes after storage. A total of 120 semi-trained panelists participated in the organoleptic test. The Hedonic Scale Scoring method (preference test) with a scale ranging from 1 (strongly disliked) to 7 (strongly liked) was used for the organoleptic test.

2.10. Extraction of Tomatoes

A 50 g piece of tomato was sliced and blended for 30 s. Then, 50 g of distilled water was added as a solvent for extraction. The extraction process was conducted using a beaker with a magnetic stirrer for 3 h. Then, the tomato slurry was filtered using a smooth fabric cloth. Finally, the filtrate was collected and freeze-dried for 72 h. A 0.25 g freeze-dried sample was diluted in 25 mL of distilled water for analysis.

2.11. Qualitative Analysis

Qualitative analysis was performed for phytochemicals, such as alkaloids, saponin, tannin, and cardiac glycoside. In addition, reducing sugar was also examined qualitatively. The result is expressed as a numbering scale. The highest number represents the highest content of phytochemicals and reducing sugar in the sample, as indicated by the strong color intensity formed by the chemical reaction.

a. Alkaloids

In brief, 1 mL of extract was placed in a test tube. Then, 1 mL of chloroform containing one drop of ammonia and five drops of 5 M H_2SO_4 was added. The tube was then vortexed, and the mixture was pipetted into two spot plates with three drops for each spot. Finally, the Mayer and Wagner reagents were added to spot plates I and II. For spot plate I, the result is positive if the white color is formed. Meanwhile, the brown color indicates a positive test result for spot plate II [23].

b. Saponin and Tannin

Two test tubes were prepared with 3 mL of extract added for each tube. For the saponin test, the test tube was vertically sonicated for 10 s and let rest for 10 min. The existence of saponins in the extract can be observed from the presence of a stable foam. Meanwhile, the test tube was heated for 10 min for the tannin test, and 5 mL of $FeCl_3$ solution was added. If the sample contains tannin, the solution will turn to dark blue color [23].

c. Cardiac glycoside and reducing sugar

Briefly, 1 mL of extract was placed in a test tube, and 1 mL each of Fehling A and Fehling B were added. The tube was then vortexed and heated for 10 min in a water bath.

The resulted color was observed visually [23]. Meanwhile, for reducing sugar, a similar sample volume was added to 2 mL of Benedict reagent, and then the mixture was boiled for 5 min in the water bath. The brick-red cuprous oxide precipitate will be observed [24].

2.12. Total Phenolic Content

The phenolic compound was measured according to [25]. In brief, 0.5 mL of extract was placed in a test tube, and 1 mL of Folin Ciocalteau reagent was added. The mixture was vortexed and stored for 5 min. After that, 2 mL of 2.5% Na_2CO_3 and 4 mL of distilled water were added to the mixture, immediately vortexed, and stored in a dark place for 30 min. The absorbance of the mixture was measured at 760 nm. The result of absorbance was plotted in a gallic acid standard curve. The result was expressed as mg gallic acid equivalent/100 g sample.

2.13. Total Flavonoid Content

The flavonoid content was examined based on a previous report by [26]. An amount of 0.5 mL of extract was mixed with 0.3, 0.3, and 2 mL of 5% $NaNO_2$, 10% $AlCl_3$, and 1 M NaOH, respectively, in a 10 mL volumetric flask. After that, the distilled water was added to the volume. The mixture was then homogenized. The absorbance of the mixture was measured at 510 nm. The catechin and distilled water were used as standard and blank, respectively, and the result was expressed as mg catechin equivalent/g sample.

2.14. Lycopene Content

The lycopene content of the sample was measured spectrophotometrically [27]. In brief, the fresh tomatoes were blended, and 5 g of tomato puree was placed in a beaker glass covered with aluminum foil. Then, 50 mL of hexane: acetone: ethanol (2:1:1) solvent was added. The mixture was homogenized using a magnetic stirrer. After that, the mixture was placed into a separating funnel, and 10 mL of distilled water was added. The mixture was shaken vigorously for 15 min. The upper layer of the mixture was collected, placed in a 50 mL volumetric flask, and filled up with a similar solvent. The mixture was then homogenized, and absorbance was measured at 513 nm. The lycopene content was express as mg/kg sample.

2.15. Antioxidant Activity

a. DPPH Method

The capacity of extract in the scavenge DPPH radical was determined according to [28]. Briefly, the mixture of 1 mL of extract, 2 mL of 0.2 M DPPH, and 2 mL of methanol was homogenized and stored for one h in a dark room. After that, the absorbance was determined using a spectrophotometer at 517 nm. BHT was used as a control. The result of the scavenging capacity of the extract was expressed as follows: % radical scavenging capacity = ((Absorbance of control − Absorbance of the sample)/absorbance of control) × 100%.

b. Ferric Reducing Antioxidant Power FRAP

The FRAP method was performed according to [25]. Briefly, 60 µL extract, 180 µL distilled water, and 1.8 mL FRAP reagent was mixed in a centrifuge tube and homogenized. The mixture was then incubated at 37 °C for 30 min. The absorbance of the mixture was measured spectrophotometrically at 593 nm. Meanwhile, Fe [II] ($FeSO_4.7H_2O$, with the range of 100–2000 mM) was used to create a standard curve. The result of FRAP was expressed as mmol Fe[II]/g.

2.16. Statistical Analysis

The experiments were carried out using a completely randomized design with three replications. Data were expressed as means ± SD. The Student's t test was performed to determine the significant differences in parameters between the coated and non-coated

tomatoes. The analysis was performed using SPSS v23, IBM, New York, United States with statistical significance set at $p < 0.05$.

3. Results and Discussion

Respiration produces energy that the tomato can use to carry out metabolic processes in the ripening stage to reach the fully matured stage and leads to the senescence stage [29]. Providing an edible coating as the outer layer of tomatoes could potentially prolong the shelf life of tomatoes.

Based on the determination, the moisture content of both coated and non-coated tomatoes decreased during storage. Nevertheless, there was a difference in the amount of moisture content decrease between coated and non-coated tomatoes (Figure 1A). Non-coated tomatoes had an initial moisture content of 94.44 ± 0.08%, and after being stored for 12 days, the moisture content reached 92.97 ± 0.34%. Meanwhile, tomatoes with edible coating did not lose as much moisture content as non-coated tomatoes. Tomato fruit coated with *A. vera* gel had an initial moisture content of 95.11 ± 0.04%, and after being stored for 12 days, the moisture content of the tomato fruit became 94.24 ± 0.29%. The result shows that the decrease in moisture content of non-coated tomatoes (1.47%) is higher than that of coated tomatoes (0.87%). The statistical analysis performed observed a significant difference in the loss of moisture between the coated and non-coated tomatoes. Therefore, the *A. vera* gel was shown as an effective coating agent in maintaining the moisture content of tomatoes during storage.

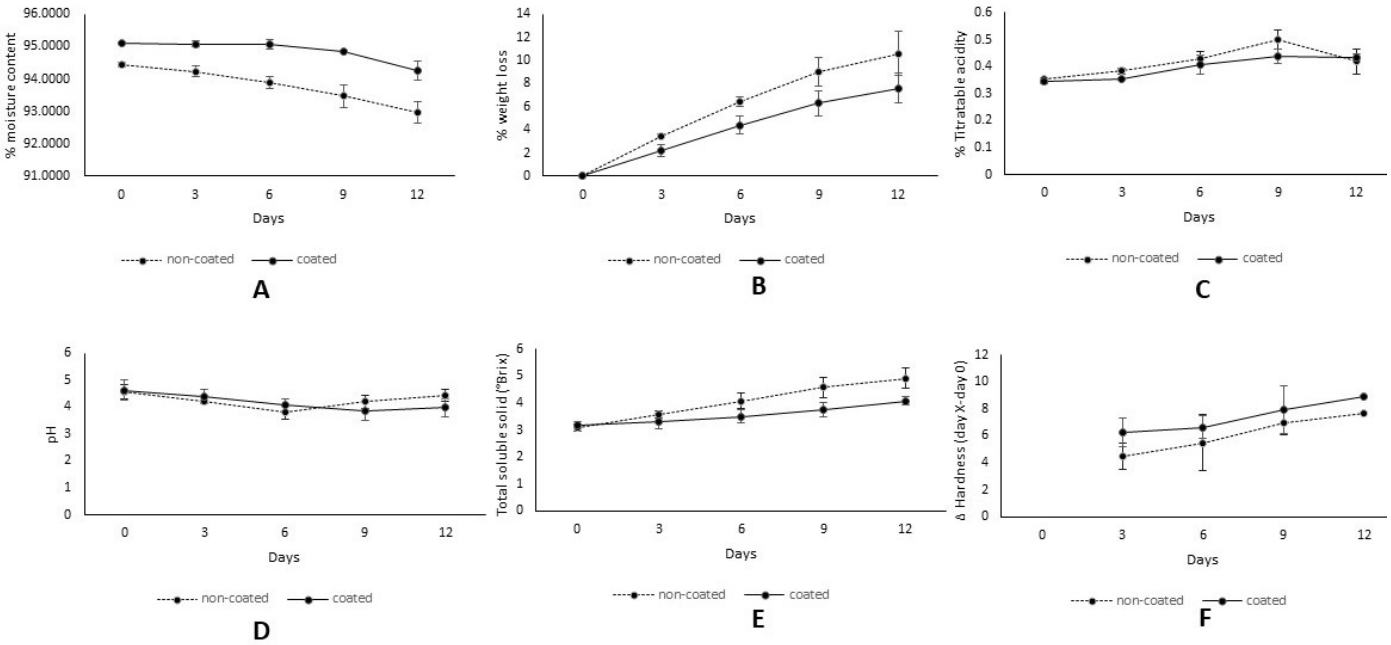

Figure 1. The effect of *A. vera* edible coating on (**A**) moisture content, (**B**) weight loss, (**C**) titratable acidity, (**D**) pH, (**E**) total soluble solid, and (**F**) hardness of tomatoes.

The decrease in moisture content in tomatoes was caused by the respiration and transpiration processes during storage. The water content of fruit will reduce during storage caused by the transpiration process, which evaporates water in the fruit tissue [30]. A thin coating layer of *A. vera* gel on the surface of tomatoes can inhibit the exposure of fruit to oxygen, thus delaying the respiration process. In addition, the *A. vera* gel coating layer could act as a barrier and reduce the water evaporating from the fruit due to transpiration, thus maintaining the water content of the fruit [31]. This result is in line with a previous report that the edible coating can modify the surrounding atmosphere of the fruit by forming a semipermeable layer, protecting the fruit from excessive water losses and exposure to oxygen [32]. Meanwhile, Allegra et al. [33], who applied *A. vera* gel

as an edible coating on fig fruit, which is also a climacteric fruit, suggested a significant decrease in moisture content during storage. Therefore, the presence of an edible coating could lower the reduction rate of moisture content. Moreover, Mendy et al. [34] worked on papaya fruit stored at room temperature. A smaller decrease was observed on papaya coated with *A. vera* gel.

The percentage of weight loss is the decrease in the weight of the tomato during storage compared to the initial weight. Weight loss is a crucial parameter for the quality of tomatoes. The weight loss of tomatoes caused by the decrease in moisture content could negatively influence the sensory properties of tomatoes, especially their fresh appearance [35]. The more significant moisture loss gave a negative appearance to the wrinkled skin of the tomato, which could decrease consumer acceptance. The results showed that non-coated tomatoes had a higher weight loss percentage (10.59%) than coated tomatoes (7.62%) (Figure 1B). Furthermore, a significant difference was observed between non-coated and coated tomatoes on the weight loss percentage during storage. *A. vera* gel as an edible coating can prevent excessive weight loss by inhibiting the transpiration process and limiting the oxygen contact with the fruit so that the respiration rate of tomatoes can be inhibited [36]. Meanwhile, a positive correlation between the percentage of weight loss and the moisture content indicates that the evaporation of water mainly contributes to the weight loss of tomatoes during storage.

Figure 1C illustrates the change in total titratable acidity of coated and non-coated tomatoes during storage. An increased trend in titratable acidity was observed until the ninth day of storage, which was 0.34 to 0.43% for the coated group and 0.35–0.49% for the non-coated group. After nine days, the titratable acidity was decreased to 0.43 and 0.41% for the coated and non-coated tomatoes, respectively. Even though on the 12th day, the non-coated tomatoes experienced a higher decrease than the coated tomatoes, there was no significant difference observed. The change in total acid can describe the respiration pattern of tomatoes. If the respiration rate of tomatoes increases, the total acidity of tomatoes can increase, and vice versa. As a climacteric fruit, during storage, the respiration rate of the tomato is increasing, which influences the titratable acidity [37]. After a certain number of days, the respiration rate decreased, and the organic acids declined. A decrease in the respiration rate caused a decrease in the percentage of total acid and the use of organic acids for metabolic processes. Therefore, the titratable acidity was decreased. The application of *A. vera* gel can reduce the fruit's respiration rate because it minimizes tomatoes' exposure to O_2. *A. vera* gel can create a wax-like layer on the surface of the fruit so that it can reduce the penetration of gases such as O_2 and CO_2, thus reducing the respiration rate, ethylene production, and ripening stage and inhibiting senescence [38].

The pattern of pH change in coated and non-coated tomatoes is shown in Figure 1D. The pH of non-coated tomatoes decreased from 4.56 to 3.39 from day 0 to day 6, respectively. Meanwhile, a slight increase was observed on day 9 and day 12. A similar pattern was observed for coated tomatoes. Nevertheless, until day 6, the decrease in pH value was lower compared to non-coated tomatoes. Further storage on days 9 and 12 showed a lower pH value (3.85 and 3.89, respectively). According to Mohammadi et al. [39], the increase in pH could be due to the decline of the organic acid available and the low rate of formation. From the result, it can be suggested that non-coated tomatoes have a faster respiration rate, thus entering the post-climacteric stage earlier. Furthermore, Adiletta et al. [40] reported that the pH of non-coated figs is higher compared to coated figs because organic acids are used as substrates for enzymatic reactions in the respiration process. Therefore, the non-coated fruit has a faster respiration rate, indicated by the higher increase in pH [41].

The total soluble solids (TSS) determination can reflect the fruit's maturity level. Soluble solids widely found in fruits are glucose, fructose, and maltose. The results (Figure 1E) showed that during storage, an increase in total soluble solids was observed for both treatments and with the coated tomatoes and was found to be lower. Coated tomatoes' TSS increased from 3.17 on day 0 to 4.08 on day 12. Meanwhile, for non-coated tomatoes, the pH increased from 3.08 to 4.92 from day 0 to day 12, respectively. The result indicates

that the ripening process of coated tomatoes is slower than non-coated tomatoes. During ripening, the polysaccharides are hydrolyzed into their simple form, such as reducing sugar and other water-soluble compounds and used as the respiration substrate [42]. Therefore, the higher the maturity level of the tomatoes, the higher the TSS value, which means that the tomatoes become sweeter. On the other hand, the *A. vera* gel coating caused the minor incline of the TSS of tomatoes, which could be due to the inhibition of respiration, which reduces the energy uptake that consequently decreases the hydrolysis of polysaccharides into a soluble solid [43].

Meanwhile, the result of the hardness of the tomatoes is presented in Figure 1F. Both treatments show a decrease in hardness during storage. The data present the difference between hardness in days of storage with initial hardness (day 0). For coated tomatoes, the differences on day 3 and day 12 were 6.27 and 8.89, respectively. Meanwhile, for non-coated tomatoes, the difference between day 3 and day 0 was 4.53, and day 12 and day 0 was 7.76. The longer storage time resulted in the continuous decrease in hardness due to the ripening process. The hardness decrease needs to be carefully monitored because the further decline of hardness is associated with the low quality of tomatoes. The reduction in tomato fruit hardness is caused by respiration and transpiration processes. These processes break down carbohydrates into simpler compounds and cause a tissue rupture, thus leading to a softer texture [44]. Moreover, the metabolism of tomatoes can degrade the pectin, a substance responsible for wall integrity of fruit, into more minor water-soluble compounds with the help of the enzymes polygalacturonases and pectinmethylesterases, resulting in the texture softening of the fruit wall [45]. The non-coated treatment had a higher hardness decrease due to the tomatoes' metabolism. The *A. vera* coating agent inhibits the metabolism process, significantly reducing the work of enzyme-converting protopectin into water-soluble pectin [46]. Esmaeili et al. [47] reported that coating strawberries with *A. vera* gel could prevent the softening of the fruit tissue.

The changes in the color of the fruit are affected by metabolic activity. In this research, the lightness, redness, yellowness, hue, and chroma were determined, and the results are presented in Table 1. The lightness result shows a decrease in the coated and non-coated tomatoes due to the increase in the ripeness. The data are presented as the difference in lightness between certain days of storage with the initial (day 0) value. For coated tomatoes, values on day 3 were 1.24, increased gradually, and reached 6.13 on day 12. Meanwhile, for non-coated tomatoes, the value increased from 2.2 on day 3 to 16.5 on day 12. This result is supported by a previous finding, which reported a decrease in the lightness value of mango during storage, with the uncoated one having a lower lightness than the coated one [48]. Meanwhile, the redness result (a*) shows an increase in the tomatoes redness value during storage, with the uncoated tomatoes having a higher redness value than the coated tomatoes. It can be concluded that the changes in color in uncoated tomatoes are faster. The presence of an edible coating can inhibit the formation of redness in tomatoes. Fruit coatings can reduce the ethylene formation rate, thus delaying the maturity, chlorophyll degradation, anthocyanin accumulation, and carotenoid synthesis [36]. The color changes in tomatoes were in line with the duration of storage as the ripening stage occurred. During ripening, the chlorophyll present in the thylakoids is degraded, and lycopene accumulates in the chromoplasts [49]. Previous research observed that *A. vera* gel as a coating agent of mango could inhibit the chlorophyll degradation, thus delaying the red color formation [50]. In contrast with the redness, the yellowness of tomatoes (b*) declined in both treatments. The non-coated tomatoes show a higher yellowness decrease than the coated group. For example, on day 0, the yellowness value was 1.23; on day 12, the difference in the yellowness value was larger, at 6.68. Meanwhile, for non-coated tomatoes, the difference in the yellowness value was larger, with 6.51 for day 3 and 15.94 for day 12. The non-coated tomatoes show a higher yellowness decrease than the coated group. The edible coating could inhibit the yellowness formation of tomato. The metabolic process of tomatoes during storage leads to the red color formation given by lycopene. The dominance of lycopene outdoes the contribution of carotenoids and xanthophyll in

providing the yellow color of a tomato. The °Hue in coated tomatoes was decreased for both treatments. The edible coating significantly inhibited the respiration and transpiration rate of tomatoes, thus minimizing color changes. A similar trend was observed for chroma value. Aghdam et al. [51] observed a decrease in chroma during storage.

Table 1. Color changes in tomato during storage.

Parameters	Treatment	Δ Color (Day X-Day 0)			
		3	6	9	12
Lightness	Coated	1.24 ± 0.29	1.57 ± 0.48	3.72 ± 1.11	6.13 ± 1.11
	Non-Coated	2.24 ± 0.73	5.38 ± 0.48	14.82 ± 1.10	16.5 ± 1.10
Redness	Coated	1.23 ± 0.61	2.57 ± 0.67	3.69 ± 0.79	4.23 ± 0.46
	Non-Coated	3.11 ± 0.73	5.17 ± 1.02	6.35 ± 1.20	6.71 ± 0.53
Yellowness	Coated	2.46 ± 0.91	4.42 ± 1.23	5.31 ± 0.80	6.68 ± 0.76
	Non-Coated	6.57 ± 0.872	9.80 ± 1.25	14.08 ± 1.82	15.95 ± 1.32
°Hue	Coated	2.07 ± 0.40	4.23 ± 0.37	5.83 ± 0.69	7.43 ± 0.80
	Non-Coated	4.94 ± 1.01	8.47 ± 1.40	11.70 ± 1.91	13.18 ± 0.63
Chroma	Coated	2.02 ± 1.03	3.46 ± 1.33	3.92 ± 0.96	4.85 ± 1.02
	Non-Coated	5.80 ± 0.71	8.46 ± 1.14	12.04 ± 1.61	13.79 ± 1.36

In this research, the organoleptic test was also performed. The results in Table 2 show that on day 9, the non-coated tomatoes were preferred by the panelists for the color because they had a more intense red color than the coated tomatoes. The presence of an edible coating could inhibit the maturity stage, thus preventing the red color formation of tomatoes. Meanwhile, for appearance, gloss, and texture, the coated tomatoes were chosen by the panelists because the coating could delay the shrinkage of the fruit wall and thus create a pleasant overall appearance of the tomatoes. At the same time, applying an edible coating could create a glossy surface for fruit [52]. Furthermore, the inhibition of tomato metabolism by the edible coating could retain the rigid texture of the tomatoes preferred by the panelists.

Table 2. Organoleptic properties of tomato stored for 9 days.

Parameters	Treatment	Score
Color	Coated	3.64 ± 0.24
	Non-Coated	4.44 ± 0.31
Skin appearance	Coated	2.71 ± 0.18
	Non-Coated	1.54 ± 0.11
Glossy	Coated	2.88 ± 0.27
	Non-Coated	2.19 ± 0.14
Texture	Coated	3.05 ± 0.33
	Non-Coated	1.98 ± 0.17

Tomato is well known as a healthy food commodity because it possesses various bioactive compounds that could act as antioxidants. Phytochemical components can act as antioxidants because they can inhibit the free radical reaction of oxidation, which is responsible for the cell damage that leads to various diseases [53]. In this research, the bioactive compound of coated and non-coated tomatoes, which were stored for twelve days, was quantified and examined for its antioxidant capacity. Identification of phytochemical compounds was performed qualitatively before the quantitative analysis. Several studies have stated that phytochemical compounds contained in tomatoes include saponins, alkaloids, flavonoids, phenols, and carotenoids [54]. The results of phytochemical identification can be seen in Table 3. The tomato sample possesses alkaloid, phenolic, flavonoid, and saponin contents. Meanwhile, triterpenoids, sterol, and tannin were absent. The longer storage time increased such compounds, and the non-coated tomatoes indicate higher phytochemical contents. In addition, reducing sugar was also observed to increase with the storage time.

The rise in reducing sugar content was due to the breakdown of polysaccharides into simple sugars used for metabolism [55].

Table 3. The qualitative identification of phytochemical compounds in tomato *.

Compounds	Day 0		Day 3		Day 6		Day 9		Day 12	
	C	NC	C	NC	C	NC	C	NC	C	NC
Alkaloids	1	1	2	2	2	2	2	2	2	2
Phenolic	1	1	2	3	2	2	2	2	2	2
Flavonoid	1	1	2	2	2	2	2	2	2	2
Triterpenoids	-	-	-	-	-	-	-	-	-	-
Sterol	-	-	-	-	-	-	-	-	-	-
Saponin	1	1	2	3	3	4	4	5	5	6
Tannin	-	-	-	-	-	-	-	-	-	-
Reducing Sugar	1	1	2	3	3	4	4	5	5	6

C: coated tomato; NC: non-coated. * The highest number represents the highest content of phytochemicals and reducing sugar in the sample.

The increase in phenolic content was observed on the third day (5.88 mg GAE/g and 5.60 mg GAE/g, for non-coated and coated tomatoes, respectively) and started to reduce on the sixth day of storage (5.43 mg GAE/g and 5.51 mg GAE/g for non-coated and coated tomatoes, respectively (Figure 2A). Even though the phenolic compound of coated tomatoes was lower compared to the non-coated, = there was no significant difference found. The decline in phenolic content in non-coated tomatoes was higher compared to the coated group. The phenolic content in climacteric fruit was lessened during the ripening process [56]. Meanwhile, the rise in phenolic contents could be due to the breakdown of cell wall components. Therefore, the phenolic compounds initially located in the vacuole in the form of bound phenolics become accessible as free phenolics [57]. As a result, the total phenol of the coated tomatoes was slightly lower than the non-coated group. This result is in line with a previous report by Riaz et al. [58], where the phenolic content of non-coated fruit was higher compared to the coated group. The edible coating acts as a barrier from the surrounding environment, which could inhibit the catabolism reaction used for energy for the ripening stage. A previous report suggested that the decrease in phenolic compounds can also be due to the autoxidation reaction of phenol compounds by oxygen and light [59].

The individual flavonoid compounds of tomato include naringenin, the flavanone group, rutin, kaempferol, and quercetin [60]. A similar pattern with phenolic content was observed in the flavonoid content of tomatoes (Figure 2B). On day 3 and day 6, the coated tomatoes had a total flavonoid of 0.8066 mg CE/g and 0.8116 mg CE/g, respectively. Meanwhile, for non-coated tomatoes, the flavonoid content on days 3 and 6 was 0.8648 mg CE/g and 0.7812 mg CE/g, respectively. The analysis confirmed that there was no significant difference observed between coated and non-coated tomatoes on flavonoid content. A similar result could be explained by flavonoids being the most prominent components of the phenol group. Therefore, the edible coating could decelerate the tomato metabolism, thus reducing the flavonoid content. Meanwhile, the edible coating could inhibit the rapid decrease in flavonoid content during storage. Such functions are related to the capability of the coating as the barrier between the air and moisture from the environment [61].

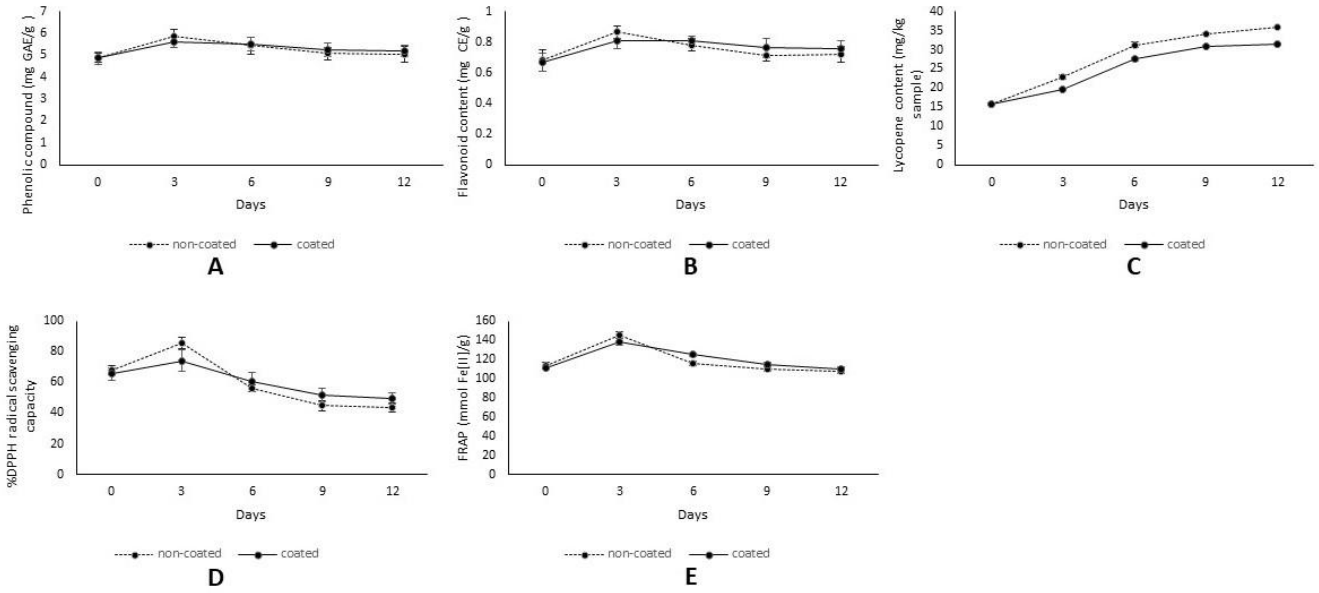

Figure 2. The effect of *A. vera* coating on (**A**) phenolic content, (**B**) flavonoid content, (**C**) lycopene content, (**D**) DPPH radical scavenging capacity, and (**E**) Ferric Reducing Antioxidant Power of tomatoes.

Results in Figure 2C showed an increase in lycopene content during storage. For coated tomatoes, the lycopene content increased from 15.77 mg/kg on day 0 to 31.48 mg/kg on day 12 of storage. Meanwhile, for non-coated tomatoes, the lycopene content raised from 15.74 mg/kg on day 0 to 35.74 mg/kg on day 12. There was a significant difference observed between coated and non-coated tomatoes in flavonoid content. During the ripening stage, lycopene content was increased due to degradation of chlorophyll and accumulation of lycopene in fruit [62]. Previous reports observed the increase in lycopene in stored tomatoes. During storage, the non-coated tomatoes exhibited a higher increase in lycopene content than the coated group and the delay of color change in the *A. vera*-coated fruit. The application of *A. vera* as a coating agent prevents the degradation of chlorophyll and the accumulation of lycopene in the ripening stage. In addition, the *A. vera* coating act as a barrier to air and moisture, thus decreasing the respiration rate of fruit [63,64].

Furthermore, the antioxidant activity of tomatoes was examined using DPPH and FRAP methods. The result shows that the tomato extract can scavenge DPPH radicals (Figure 2D). The coated tomatoes had a 65.6% radical scavenging activity on day 0 and slightly increased on day 3 to 74.12%. Further storage resulted in decreased antioxidant activity. On day 12, the antioxidant activity of tomatoes reached 49.57%. A similar pattern was observed for non-coated tomatoes. The highest antioxidant activity was possessed by tomatoes on day 3, with 85.57%. A positive correlation (R = 0.3281) was observed between the extract's phenolic content and antioxidant activity. The phenolic compound was reported to have high antioxidant activity, mainly due to its ability as a hydrogen donor to stabilize free radicals [65]. However, after the third day of storage, the antioxidant activity of the tomatoes declined. The result is also in line with the decrease in phenolic content. In addition to the lower phenolic compound content, the decrease in DPPH radical scavenging activity during storage could be due to the bioactive compound in fruit being susceptible to degradation when stored in an open environment. Such storage exposes the fruit to oxidation, which is also accelerated by the presence of light and high-temperature storage. Meanwhile, a similar trend was observed for the FRAP method (Figure 2E). The tomato extract could reduce the ferric to ferrous ion. The coated tomatoes on day 0 had 111.02 mmol Fe[II]/g and increased to 138.21 mmol Fe[II]/g on day 3. Further storage decreased the antioxidant activity to 110.21 mmol Fe[II]/g on day 12. A similar pattern was found for non-coated tomatoes, with tomatoes stored for 3 days having the highest antioxidant activity (145.43 mmol Fe[II]/g) and the tomatoes stored for 12 days having the

lowest antioxidant activity (107.64 mmol Fe[II]/g). The phenolic content plays a vital role in the antioxidant capacity of tomato extract by acting as a chelating agent. Even though the lycopene content was increased, it does not contribute significantly to the antioxidant capacity due to its nature as a lipophilic substance. The hydrophilic substance is dominant in acting as an antioxidant compared to the lipophilic [66].

4. Conclusions

The application of *A. vera* gel edible coating could prolong the shelf life of tomatoes, as observed from the color measurement and organoleptic test. In addition, the *A. vera* edible coating could decrease the loss of moisture content and weight of tomatoes, which further affects the freshness of tomatoes. Furthermore, the edible coating can inhibit the maturity stage, as shown in the titratable acidity, pH, and total soluble solids. Meanwhile, the coating process could retain the hardness of the tomato. From the organoleptic test, the non-coated tomatoes were preferred by the panelists for the color, but for the glossiness, skin appearance, and texture, the coated tomatoes were preferred. Moreover, the presence of *A. vera* gel could minimize the degradation of phenolic and flavonoid compounds while inhibiting lycopene production, thus protecting the ability of tomatoes to act as an antioxidant and affecting the color of tomatoes that may influence the consumer acceptance. Based on these properties, *A. vera* could potentially be used for coating other fruit commodities. It could also be mixed with hydrocolloids to construct a film suitable for food packaging applications.

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