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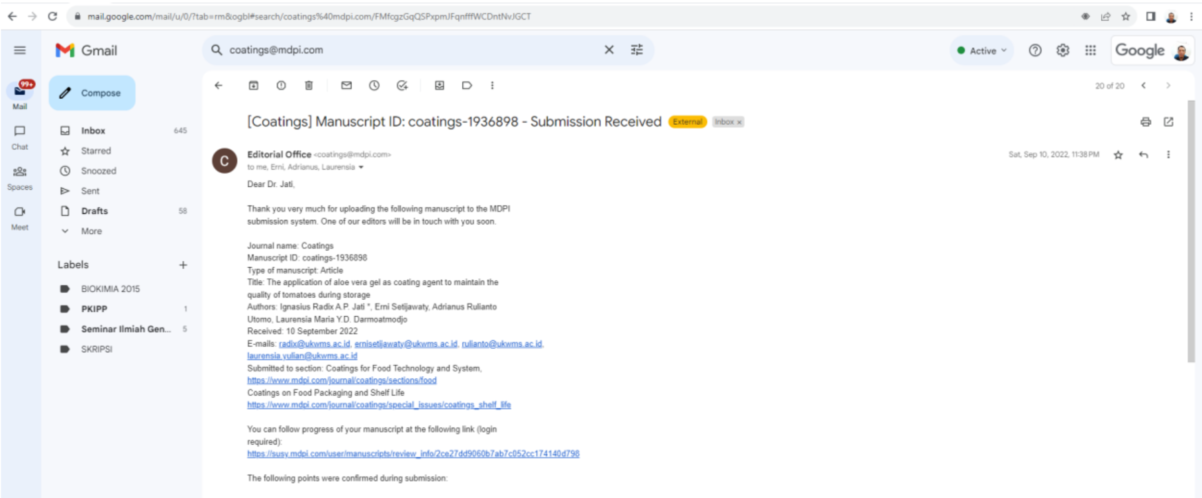

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Article

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 aloe vera gel can be used as an ingredient for edible films or coatings. The edible film can also be applied to fresh fruit and vegetables using the coating principle. Tomatoes are one of the fruits commodities that can be maintained in terms of quality during storage using the edible coating. This study aims to determine the effect of edible coating made from aloe vera on tomatoes' physical, chemical, and organoleptic properties during storage. The aloe vera gel was prepared and used for coating the tomato, and the tomato was 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 application of aloe vera could prolong the shelf life of tomatoes. In addition, Aloe vera edible coating decreases moisture content and weight loss. Furthermore, the edible coating affects the titratable acidity, pH, and total soluble solids. Meanwhile, the coating process could retain the hardness of the tomato. Moreover, the degradation of phenolic and flavonoid compounds, inhibiting lycopene production and maintaining antioxidant activity, was observed.

Keywords: tomato, aloe vera, edible coating, storage

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1. Introduction

Aloe vera is a plant from the Liliaceae family extensively distributed in Middle East and Africa. This plant is widely grown in tropical and subtropical areas, including Indonesia, due to its resistance to dry conditions because of the ability to absorb water and store in a longer time, therefore equipped the plant with sufficient water to live in the drought and extreme dry condition [1]. Aloe 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 aloe vera, drinks, and snack mixes. However, the utilization of Aloe vera is limited to food products because it naturally tastes bitter when consumed [3].

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

The presence of polysaccharide components in aloe 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]. 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 or packaging of food products and at the same time can be directly consumed. The main goal of developing edible films or coatings is to create an environmental-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 product from damage. Moreover, the edible film and coating can also carry preservative agent, flavoring agent, and colorant to extend the shelf-life, enhance the flavor, and improve the appearance of food and food product [7]. Some food products that often found using edible packaging are candy, chocolate, sausage, dried fruit, and bakery products [8].

The edible film can also be applied to fresh fruit and vegetables using the coating principle. Enormous percentage of postharvest losses especially for fruit and vegetables has been major challenges in the developing countries to ensure the food security status. In contrast to edible films that is 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 fruit and vegetables because it will decrease the contact to oxygen, respiration rate, and generally affect the metabolism of fruits and vegetables, thereby preventing the spoilage of fruits [9]. In addition, the presence of 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 [10]. Due to its 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 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

Tomatoes are one of the fruits commodities that can be maintained in terms of quality during storage using the edible coating. Tomato, as a climacteric fruit, is susceptible to post-harvest damage. 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 of respiration rate and the growth of microbes, thus accelerating spoilage. Research on the application of edible coatings on tomatoes has been reported [11], generally using various starch and hydrocolloids. However, limited research is available on the edible coatings made from aloe vera to maintain the physical, chemical, and organoleptic qualities of tomato during storage. Therefore, this study aims to determine the effect of edible coating made from aloe vera on tomatoes' physical, chemical, and organoleptic properties during storage.

2. Materials and Methods

Aloe vera was grown in Madiun District, East Java and purchased through a national aloe vera supplier in Sidoarjo District, East Java Province, Indonesia. Meanwhile, the tomato was obtained from local farmers in Malang District, East Java Province. The tomato was harvested after 90 days. The tomato was chosen within the turning level of maturity specified by the range of yellow, light red, and red colors of approximately 10-30%. The average diameter of a tomato is 2.5±0.25 cm, weight 20±2 g for each tomato, has a slightly acidic taste, and the absence of injury. Meanwhile, the aloe vera was harvested at six months, possesses a clean green skin color, is approximately 45±4.5 cm long, weighs around 350±35 g for each rind, and has the absence of injury on the surface of the rind. Moreover, all the chemical used for analysis was purchased from Merck, Germany, and Sigma Aldrich, Singapore, unless otherwise stated

2.1. Preparation of aloe vera coating gel and coating process

The aloe vera rind was washed to remove the impurities. Then, 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 at 80°C for 5 min. After heating, the aloe vera gel was allowed to cool to room temperature. Meanwhile, the tomato was washed to remove the impurities, soaked in the aloe vera gel for 5 min, and placed in an open tray at room temperature to let the aloe 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 hours. After that, the sample was cooled in a desiccator for 10 minutes before weighing. Repeat the step until the constant weight of the sample was achieved. Finally, the sample's moisture content is 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 tomato was measured at the beginning of the experiment (day 0) after the air drying. Then, the sample was weighed every three 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 [12]. Briefly, the sample was crushed. Then, 10 g of sample was placed in a 100 mL volumetric flask and filled with distilled water. After that, the sample solution was filtered using Whatman no 42 filter paper. Then, 10 mL of sample were placed in Erlenmeyer, 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.

2.5. pH

The pH was examined using a pH meter. First, the sample was blended and filtered. Then, 100 mL of filtrate was placed in a glass beaker. Before the measurement process, the pH meter was calibrated using buffer pH 4.0 and 7.0. Next, the electrode was simmered in the sample until the stabile pH value was observed.

2.6. Total Soluble Solid

The total soluble solid of tomato was determined using refractometer. In brief, the sample was blended and filtered using a clean cloth. Then, the filtrate was collected. Finally, three drops of the sample were placed in the refractometer prism, which was cleaned beforehand using distilled water and lens paper, and the measurement was performed.

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) [13]. 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.

2.9. Organoleptic test

The organoleptic test was performed to determine sensory properties of tomato preferred by the panelist. The quality parameter 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 tomato after storage. A total of 120 semi-trained panelists participated in the organoleptic test.

2.10. Extraction of tomato

A 250 g of tomato was sliced and blended for 30 seconds. Then 250 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 hours. 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 distilled water for analysis.

2.11. Qualitative analysis

a. Alkaloids

In brief, 1 mL of extract was placed in a test tube. Then 1 mL chloroform containing one drop of ammonia and five drops of 5M H2SO4 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.

b. Saponin and Tannin

Prepare two test tubes with 3 mL of extract added for each tube. For the saponin test, the test tube was vertically sonicated for 10 seconds 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 FeCl3 solution was added. If the sample contains tannin, the solution will turn to dark blue color.

c. Cardiac glycoside

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.

2.12. Total phenolic content

The phenolic compound was measured according to [14]. 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 minutes. After that, 2 mL 2.5% Na2CO3 and 4 mL of distilled water were added to the mixture, immediately vortexed, and stored in a dark place for 30 minutes. 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 [15]. A 0.5 mL of extract was mixed with 0.3, 0.3, and 2mL of 5% NaNO2, 10% AlCl3, and 1M 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.

2.14. Lycopene content

The lycopene content of the sample was measured spectrophotometrically [16]. In brief, the fresh tomato was 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 minutes. 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.

2.15. Antioxidant activity

a. DPPH method

The capacity of extract in scavenge DPPH radical was determined according to [17]. 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 [14]. 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] ($FeSO4.7H2O$, 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.

3. Results and Discussion

Tomato is a food commodity widely used in processed food or consumed in fresh-cut form. During storage, the quality of tomatoes can quickly decrease due to continuous respiration. Tomato belongs to the climacteric fruit group, which is the fruit that experiences a dramatic increase in respiration rate during ripening, including after being harvested [18]. The respiration produces energy that the tomato can use to carry out metabolic processes in the ripening stage to reach the fully matured tomato and leads to the senescence stage. The average shelf life of fresh-cut tomatoes stored at room temperature is approximately seven days [19]. Providing edible coating as the outer layer of tomato could potentially prolong the shelf life of tomato.

The moisture content of fruit is essential in affecting the fruit's freshness, appearance, and texture [20]. 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 Aloe vera gel had an initial moisture content of 95.11±0.04%, and after being stored for 12 days, the moisture content of tomato fruit became 94.24±0.29%. The result shows that the decrease in moisture content of non-coated tomatoes is higher than that of coated tomatoes. Therefore, the Aloe vera gel was shown as an effective coating agent in maintaining the moisture content of tomatoes during storage.

The decrease of moisture content in tomatoes was caused by the respiration and transpiration processes during storage. The water content of fruit will reduce during storage caused of the transpiration process, which evaporates water in the fruit tissue [21]. A thin coating layer of Aloe vera gel on the surface of tomatoes can inhibit exposure of fruit to oxygen, thus delaying the respiration process. In addition, the Aloe 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 [22]. 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 [23]. Meanwhile, Allegra et al. [24], who applied Aloe vera gel as an edible coating on fig fruit which is also climacteric fruit, suggested a significant decrease in moisture content during storage. Therefore, the presence of edible coating could lower the reduction rate of moisture content. Moreover, Mendy et al. [25] worked on papaya fruit stored at room temperature. A smaller decrease was observed on papaya coated with aloe 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 of moisture content could negatively influence the sensory properties of tomatoes, especially their fresh appearance [26]. 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 than coated tomatoes (Figure 1B). Furthermore, a significant difference was observed in applying the edible coating to the weight loss percentage of tomatoes during storage. According to Tzortzakis et al. [27], tomato fruit weight loss tends to increase during storage. Tomato can experience weight loss during storage because of the water evaporation due to respiration and transpiration processes. Aloe 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 [28]. 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.

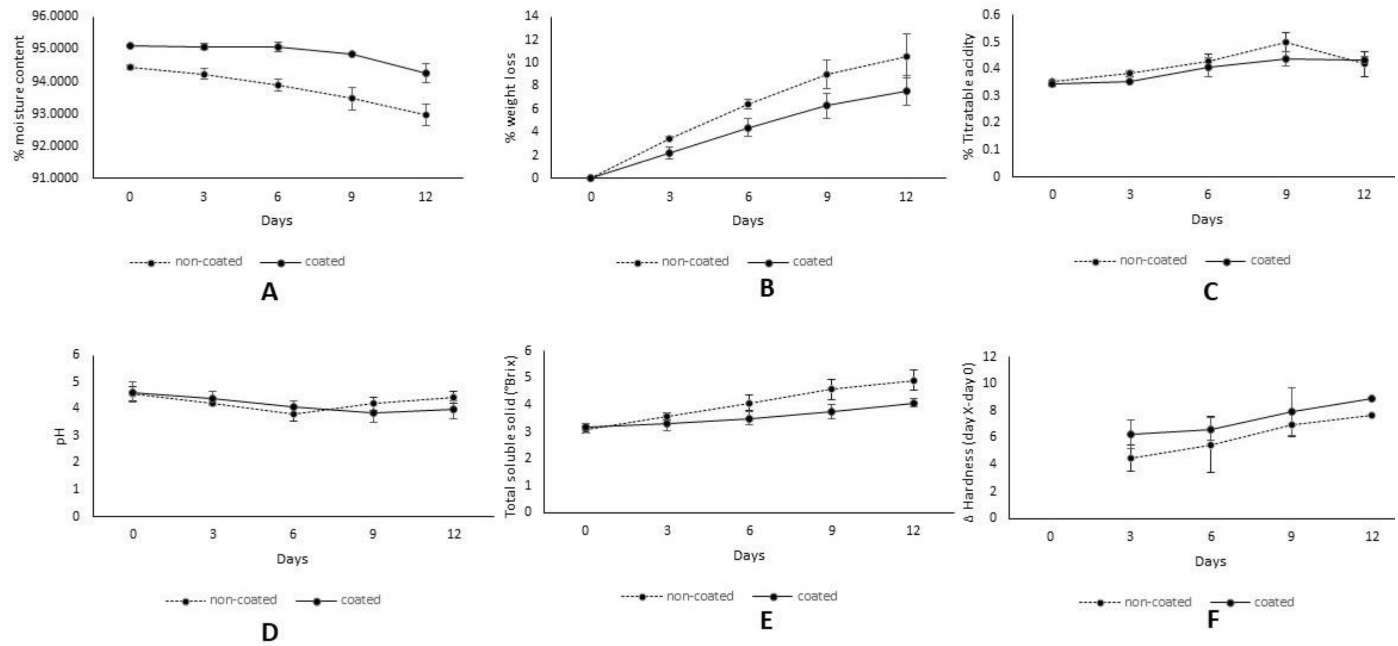

Figure 1. The effect of aloe vera edible coating on (A) moisture content, (B) weight loss, (C) titratable acidity, (D) pH, (E) total soluble solid, and (F) hardness of tomatoes

Figure 1C illustrates the change in total titratable acidity of coated and non-coated tomatoes during storage. An increase in titratable acidity was observed until the ninth day of storage. After nine days, the titratable acidity was decreased. Meanwhile, on the 12th day, the non-coated tomatoes experienced a higher decrease than the coated tomatoes. 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 climacteric fruit, during storage, the respiration rate of the tomato is increasing, which influences the titratable acidity [29]. After certain 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 Aloe vera gel can reduce the fruit's respiration rate because it minimizes tomatoes' exposure to O_2. Aloe 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, ripening stage, and inhibiting senescence [30].

The pattern of pH change in coated and non-coated tomatoes is shown in Figure 1D. According to Mohammadi et al. [31], 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. [32] 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.

The total soluble solids (TSS) determination could 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 with the coated tomatoes and was found to be lower. 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 [33]. Therefore, the higher the maturity level of the tomatoes, the higher the TSS value, which means that the tomatoes are getting sweeter. On the other hand, the Aloe 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 decrease the hydrolysis of polysaccharide into soluble solid [34].

Meanwhile, the result of the hardness of the tomato is presented in Figure 1F. Both treatments show a decrease in hardness during storage. The longer storage time resulted in the continuous decrease of 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. Moreover, the metabolism of tomatoes can degrade the pectin as a substance responsible for wall integrity of fruit into more minor water-soluble compounds with the help of enzymes polygalacturonases and pectinmethylesterases resulting in the texture softening of the fruit wall [35]. The non-coated treatment had a higher hardness decrease due to the tomatoes' metabolism. The aloe vera coating agent inhibits the metabolism process, significantly reducing the work of enzyme-converting protopectin into water-soluble pectin. Esmaeili et al. [36] reported that strawberry coated with aloe 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 result is presented in Table 1. The Lightness result shows a decrease in the coated and non-coated tomatoes due to the increase in the ripeness. This result is supported by 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 [37]. Meanwhile, the redness result (a*) shows an increase in the tomato's redness value during storage, with the uncoated tomato having a higher redness value than the coated tomato. It can be concluded that the changes of color in uncoated tomatoes are faster. The presence of edible coating can inhibit the formation of redness in tomatoes. Fruit coating could reduce the ethylene formation rate, thus delaying the maturity, chlorophyll degradation, anthocyanin accumulation, and carotenoid synthesis. The color changes of 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 [38]. Previous research observed that aloe vera gel as a coating agent of mango could inhibit the chlorophyll degradation, thus delaying the red color formation [39]. In contrast with the redness, the yellowness of tomato (b*) declined in both treatments. The non-coated tomato shows a higher yellowness decrease than the coated group. The edible coating could inhibit the yellowness formation of tomato. The metabolic process of tomato 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 tomato was decreased for both treatments. The edible coating significantly inhibits the respiration and transpiration rate of tomatoes, thus minimizing color changes.

A similar trend was observed for chroma value. Aghdam et al. [40] observed a decrease in chroma during storage.

Table 1. Colour changes of tomato during storage

Parameters	Treatment	Δ colour (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	2.2±0.7	5.3±0.48	14.8±1.1	16.5±1.1
Redness	Coated	1.23±0.61	2.57±0.67	3.69±0.79	4.23±0.46
	Non-Coated	3.1±0.7	5.1±1.0	6.3±1.2	6.7±0.5
Yellowness	Coated	2.46±0.91	4.42±1.23	5.31±0.80	6.68±0.76
	Non-Coated	6.5±0.8	9.8±1.2	14.0±1.8	15.9±1.3
Hue	Coated	2.07±0.4	4.23±0.37	5.83±0.69	7.43±0.8
	Non-Coated	4.9±1.0	8.4±1.4	11.7±1.9	13.1±0.6
Chroma	Coated	2.02±1.03	3.46±1.33	3.92±0.96	4.85±1.02
	Non-Coated	5.8±0.7	8.4±1.1	12.0±1.6	13.7±1.3

In this research, the organoleptic test was also performed. The result in Table 2. shows that on day 9, the non-coated tomato was preferred by the panelist for the color because it has a more intense red color than the coated tomato. The presence of edible coating could inhibit the maturity stage, thus preventing the red color formation of tomato. Meanwhile, for appearance, glossy, and texture, the coated tomato was chosen by the panelist because it could delay the shrinkage of the fruit wall and thus create a pleasant overall appearance of the tomato. At the same time, applying an edible coating could create a glossy surface for fruit [41]. Furthermore, the inhibition of tomato metabolism by edible coating could retain the rigid texture of tomato preferred by the panelist.

Table 2. Organoleptic properties of tomato stored for 9 days

Parameters	Treatment	Score
Color	Coated	3.64
	Non-Coated	4.44
Skin appearance	Coated	2.71
	Non-Coated	1.54
Glossy	Coated	2.88
	Non-Coated	2.19
Texture	Coated	3.05
	Non-Coated	1.98

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. In this research, the bioactive compound of coated and non-coated tomatoes, which were stored for twelve days, was quantified and examined for their antioxidant capacity. Identification of phytochemical compounds is performed qualitatively before the quantitative analysis. Several studies have stated that phytochemical compounds contained in tomatoes include saponins, alkaloids, flavonoids, phenols, and carotenoids [42]. 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 tomato indicates a higher phytochemical content. 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 [43].

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 increase of phenolic content was observed on the third day and started to reduce on the sixth day of storage (Figure 3A). The decline of 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 [44]. Meanwhile, the rise in phenolic content 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 [45]. As a result, the total phenol of coated tomato was slightly lower than the non-coated group. This result is in line with a previous report by Riaz et al. [46], 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. Previous report suggested that the decrease of phenolic can also be due to the autoxidation reaction of phenol compounds by oxygen and light [47].

The individual flavonoid compounds of tomato include naringenin, the flavanone group, rutin, kaempferol and quercetin [48]. A similar pattern with phenolic content was observed in the flavonoid content of tomatoes (Figure 3B). 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 of flavonoid content during storage. Such functions are related to the capability as the barrier of the air and moisture from the environment [49].

Results in Figure 3C showed an increase in lycopene content during storage. During the ripening stage, lycopene content was increased due to degradation of chlorophyll and accumulation of lycopene in fruit [50]. Previous reports observed the increase of lycopene in stored tomatoes. During storage, the non-coated tomato exhibits a higher increase in lycopene content than the coated group and the delay of color change in aloe vera-coated fruit. The application of Aloe vera as a coating agent prevents the degradation of chlorophyll and the accumulation of lycopene in the ripening stage. In addition, the aloe vera coating act as a barrier to air and moisture, thus decreasing the respiration rate of fruit [51,52].

Furthermore, the antioxidant activity of tomatoes was examined using DPPH and FRAP methods. The result shows that the tomato extract can scavenge DPPH radical

(Figure 3D). A positive correlation 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 [53]. However, after the third day of storage, the antioxidant activity of the tomato declined. The result is also in line with the decrease in phenolic content. In addition to the lower phenolic compound content, the decrease of 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 methods (Figure 3E). 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 [54].

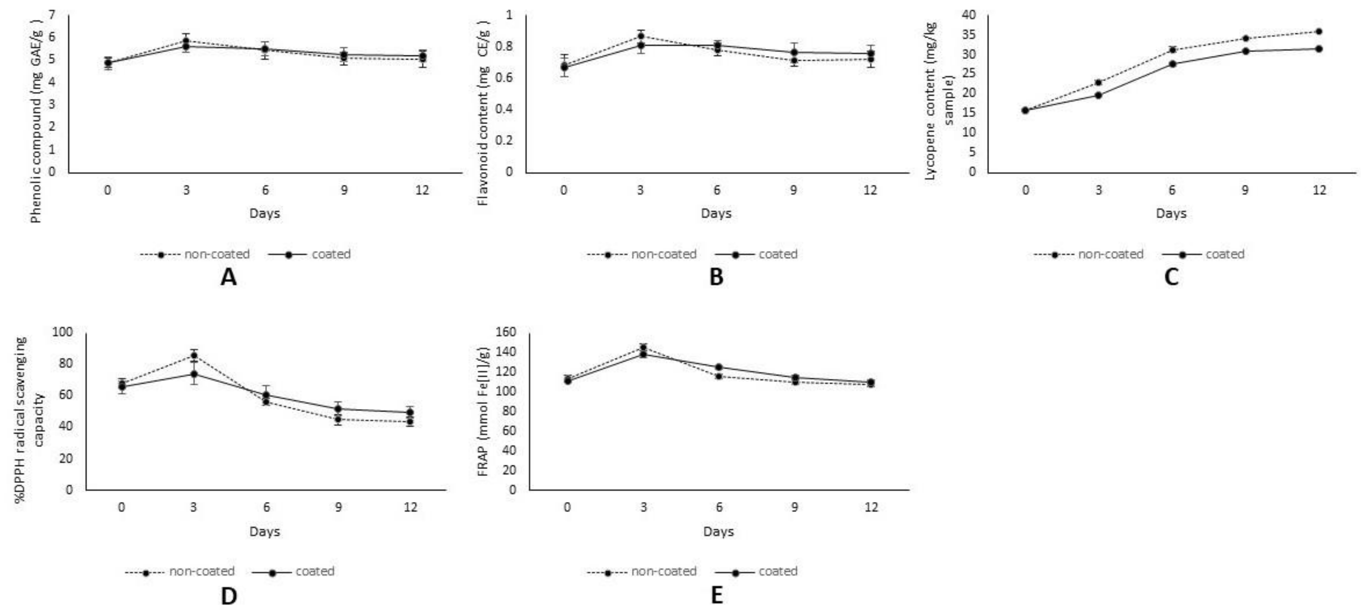

Figure 2. The effect of aloe vera coating on (A) phenolic content, (B) flavonoid content, (C) lycopene content, (D) DPPH radical scavenging capacity, and (E) Ferric Reducing Antioxidant Power of tomatoes

4. Conclusion

The application of aloe vera gel edible coating could prolong the shelf life of tomatoes, as observed from the color measurement and organoleptic test. In addition, Aloe 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. Moreover, the presence of aloe 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.

Supplementary Materials: -

Author Contributions: Conceptualization, A.R.U., E.S., I.R.A.P.J.; methodology, I.R.A.P.J., A.R.U., E.S.; software, L.M.Y.D.D.; formal analysis, I.R.A.P.J., A.R.U., E.S.; resources, I.R.A.P.J., L.M.Y.D.D.; writing—original draft preparation, I.R.A.P.J., A.R.U., E.S.; writing—review and editing, A.R.U., E.S., I.R.A.P.J; visualization, L.M.Y.D.D.; supervision, A.R.U.; project administration, E.S.; funding acquisition, I.R.A.P.J. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: data is available upon request

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Conflicts of Interest: The authors declare no conflict of interest

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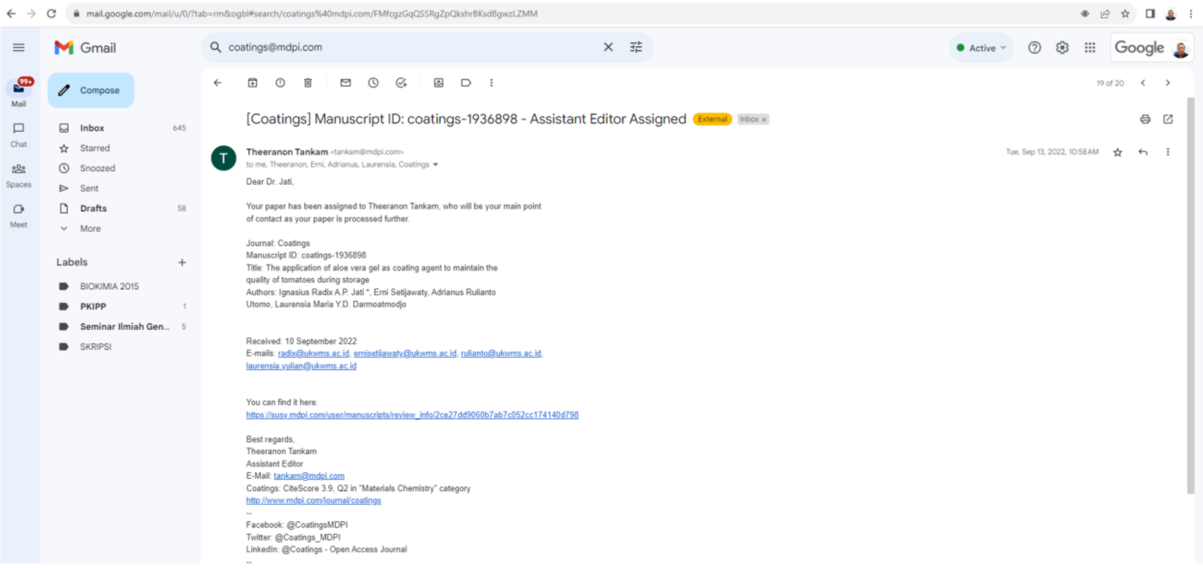
2. Bukti Assistant editor assigned.
   13 September 2022



[Coatings] Manuscript ID: coatings-1936898 - Assistant Editor Assigned

Theeranon Tankam <tankam@mdpi.com>
to me, Theeranon, Erni, Adrianus, Laurensia, Coatings

Tue, Sep 13, 2022, 10:58 AM

Dear Dr. Jati,

Your paper has been assigned to Theeranon Tankam, who will be your main point of contact as your paper is processed further.

Journal: Coatings
Manuscript ID: coatings-1936898
Title: The application of aloe vera gel as coating agent to maintain the quality of tomatoes during storage
Authors: Ignasius Radix A.P. Jati *, Erni Setijawaty, Adrianus Rulianto Utomo, Laurensia Maria Y.D. Darmoatmodjo

Received: 10 September 2022
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Best regards,
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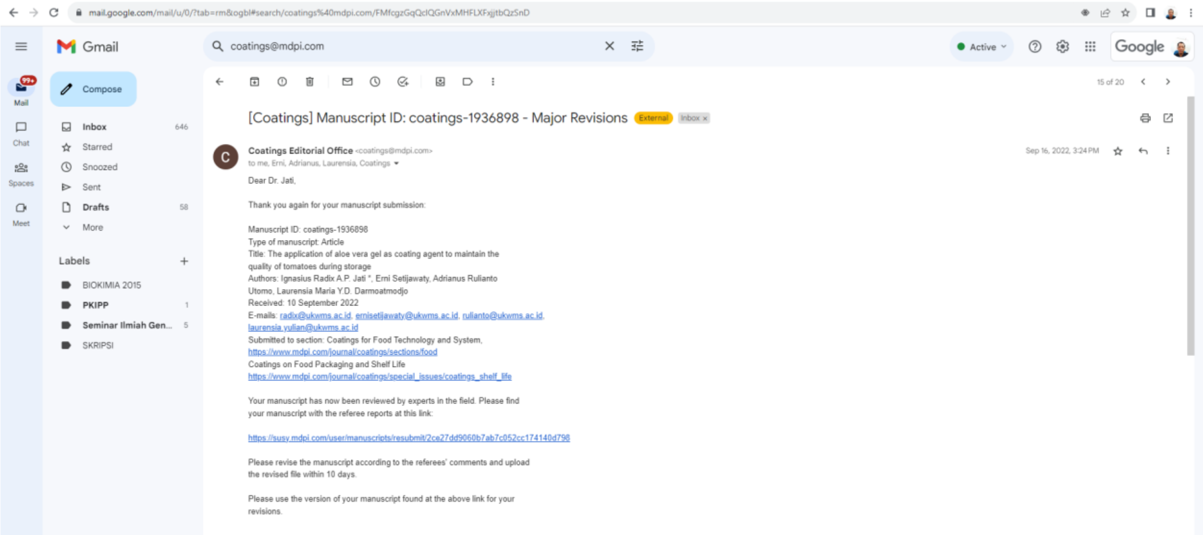
3. Bukti konfirmasi review dan hasil review
   16 September 2022



[Coatings] Manuscript ID: coatings-1936898 - Major Revisions

Coatings Editorial Office <coatings@mdpi.com>
to me, Erni, Adrianus, Laurensia, Coatings

Sep 16, 2022, 3:24 PM

Dear Dr. Jati,

Thank you again for your manuscript submission:

Manuscript ID: coatings-1936898
Type of manuscript: Article
Title: The application of aloe vera gel as coating agent to maintain the quality of tomatoes during storage
Authors: Ignasius Radix A.P. Jati *, Erni Setijawaty, Adrianus Rulianto Utomo, Laurensia Maria Y.D. Darmoatmodjo
Received: 10 September 2022
E-mails: radix@ukwms.ac.id, ernisetijawaty@ukwms.ac.id, rulianto@ukwms.ac.id, laurensia.yulian@ukwms.ac.id
Submitted to section: Coatings for Food Technology and System,
https://www.mdpi.com/journal/coatings/sections/food
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Generally, the paper have interesting experimental work but the paper cannot be considered for publication in its actual format.

Response:

Thank you for the reviewer comments, we will address all of the comments and we strongly believe that it will increase the quality of our paper.

Abstract

Line 10: Aloe vera in italics. Please correct in all the manuscripts. Moreover, *Aloe vera* in full only the first time in the text. Then you have to write *A. vera.* Please apply this advice to the whole paper.
Response:
Thank you for the suggestion. Changes have been made throughout the paper accordingly.

Lines 19-23: I suggest rewriting. At the beginning of these sentences, you use “in addition”, “furthermore”, “meanwhile”, “moreover” and all these adverbs load the concept expressed. Please rewrite.
Response:
Thank you for the suggestion. Rewriting sentences has been conducted, as seen in Lines 17-21.

Introduction

Lines 28-30: The sentence is too long and unclear.
Response:
Thank you for the comment. Changes have been made in lines 31-33.

Lines 36-39: “consist... consisting… consisting”. I suggest to change verb…there are many synonymous.
Response:
Changes have been made in lines 38-41

Lines 44-53: Please add references
Response:
References have been added in lines 49 and 55

Lines 58-63: Please add references
Response:
References have been added in lines 63 and 68

Lines 69-75: Please add references
Response:
Reference has been added in line 77

Lines 76-81: Please add references
Response:
References have been added in lines 80 and 83

Materials and methods

Lines 91-92: How many tomatoes have you used every 3 days (for 12 days) to carry out the analyses? Only one? Have you performed the analyses in triplicate?

Response:
A total of 150 tomatoes was selected, 5 tomatoes for each coating and non-coating treatment and for three replications. This information has been added in line 96-98

And then what does it mean “red colors of approximately 10-30%.”? I do not understand.

Response:
The tomato was chosen within the turning level of maturity, which means more than 10% but not more than 30% of the surface in the aggregate, showing a definite change in color from green to tannish-yellow, pink, red, or a combination thereof. Changes have been made as a response to reviewer comments.
Revision has been made in lines 98-100

Lines 122-127: How have you expressed the Tritable Acidity? Please add.
Response:
Titratable acidity was expressed as a percentage. It has been added in line 138

Lines 128-132: I do not think it is necessary to describe the calibration of the pH meter and that the electrode was immersed in the sample until the stable pH value was observed. Delete it.
Response:
Thank you for the suggestion. The calibration information has been deleted.

Lines 134-138: How have you expressed the Total Soluble Solid? Please add.
Response:
The Total Soluble Solid was expressed as °Brix. This information has been added in line 147

Lines 144-147: How have you expressed the Hardness? Please add.
Response:
The result of hardness was expressed as Force (N). This information has been added in line 156

Lines 163-168: Is this a procedure developed in your lab? If not, please add reference.
Response:
Reference has been added in line 184

Lines 170-174: Is this a procedure developed in your lab? If not, please add reference.
Response:
Reference has been added in line 191

Lines 176-178: Is this a procedure developed in your lab? If not, please add reference.
Response:
Reference has been added in line 195

Line 181: Folin Ciocalteau
Response:
Correction has been made

Lines 192-193: How have you expressed the total flavonoid content? Please add.
Response:
The total flavonoid content was expressed as mg Catechin Equivalent/g sample.
Revision has been made in line 213

Lines 195-202: How have you expressed the lycopene content? Please add.
Response:
The lycopene content was express as mg/kg sample. Revision has been made in line 222-223

A statistical analysis paragraph is completely missing. I think that you have add it because you have to state how the results are expressed. In other words, have you performed your analyses in triplicate? Have you expressed as mean ± standard deviation?

Response:

Thank you for the correction. Yes, we accidentally deleted the statistical paragraph. We conducted the experiment in four replications and presented the result as mean ± standard deviation (there is an SD bar in all figures). Revision has been made. A paragraph of statistical analysis has been added in lines 241-245

Results and discussion

Lines 223-225: Please add references.
Response:
Reference has been added in line 249

Lines 236-238: You have to be more detailed, declaring your numeric results.
Response:
Thank you for the suggestion. Numeric result in the decrease of moisture content has been added in lines 258-261

Lines 260-261: You have describe and discuss better you results.
Response:
More detailed discussion, primarily numeric results, have been added in lines 285-287

Lines 276-279: It is not enough to say that a value has increased or decreased. You have to specify the numerical values because only those can make us understand the extent of the result.
Response:
More detailed discussion, primarily numeric results, have been added in lines 300-304

Lines 293-295: What are the results you got for the pH? Please improve the description
Response:
A further description has been added in lines 316-320. The pH of non-coated tomatoes was decreased from 4.56 to 3.39 on day 0 and 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 of 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).

Lines 299-300: Are these you results? As they are not, add references.
Response:
New reference has been added in line 327

Lines 306-308: As previously suggested, your results are not described. Please add.
Response:
A Further description has been added in lines 331-333. 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 on day 0 to day 12, respectively.

Lines 311-312: As previously suggested, your results are not described. Please add.
Response:
A Further description has been added in lines 343-347. The data presented the difference between hardness in days of storage with initial hardness (day 0). For coated tomatoes, the difference on day 3 and day 12 was 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

Lines 313-317: Please add references.
Response:
Reference has been added in line 352

Lines 321-323: Are these your conclusion? Or are reported in other paper? If yes, please add references.
Response:
Sentence has been removed because it was already stated in previous sentences.

Lines 328-329: As previously suggested, your results are not described. Please add.
Response:
A Further description has been added in lines 363-367. The data is 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.

Lines 335-337: Please add references.
Response:
Reference has been added in line 375

Lines 342-343: As previously suggested, your results are not described. Please add.
Response:
A Further description has been added in lines 380-384. The non-coated tomato shows 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 yellowness value was larger, with 6.51 for day 3 and 15.94 for day 12.

Lines 380-383: Please add references.
Response:
Reference has been added in line 433

Table 3: The table is not clear. What does it mean the number (from 1 to 6) reported? Further, among the compounds are listed triterpenoids, sterols and reducing sugar, how did you analyze them? In materials and methods, their sugar procedure is not described.

Response:
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 number from 1-6. The highest number represents the highest content of phytochemical and reducing sugar in the sample, as indicated by the strong color intensity formed by the chemical reaction. Additional information has been added in lines 173-177
Meanwhile, reducing sugar was examine using Benedict reagent. The method and reference have been added in line 195-198

Lines 400-445: The big defect of this paper is in the results part, as I have already told you several times previously. You need to describe the results better. You cannot you just say that there is an increase or decrease of phenolic compound, for example. How much increase or decrease? Is it significant? Without knowing the numerical results, your manuscript is greatly weakened. The graphs are not enough as it is not possible to understand the exact values that you have obtained.

Response: Thank you for the valuable suggestion.
Revision has been made in the manuscript in lines 451-456
The increase of 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 3A). Even though the phenolic compound of coated tomatoes was lower compared to the non-coated, however, there was no significant difference found

Revision has been made in the manuscript in lines 470-475
On day 3 and day 6 the coated tomato 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

Revision has been made in the manuscript in lines 480-484
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

Revision has been made in the manuscript in lines 495-499
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)

Revision has been made in the manuscript in lines 509-515
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).

Lines 432-433: You stated “A positive correlation was observed between the extract's phenolic content and antioxidant activity”. It is certainly true. Have you performed a correlation analyses? Have you calculated Pearson correlation coefficients? If yes, you have showed these results.

Response:
Yes, we performed Pearson correlation analysis, and the R= 0.3281. Technically positive, but it is a weak correlation. The R-value has been added to the manuscript line 499.

Conclusion

In this section, I suggest to add potential application, for example in packaging sector. Further, you have performed this experiment with *A. vera* and tomatoes. How can this gel edible coating also be utilized? Can it be used in the cosmetic field?

Response:
Thank you for your suggestion. Revision has been made in line 537-539.
Based on the 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. Furthermore, A. vera is already widely used in the cosmetic field. Therefore, we did not mention it in conclusion.

The manuscript entitled “The application of aloe vera gel as coating agent to maintain the quality of tomatoes during storage” is a research about the effect of the application of Aloe vera gel on the preservation of tomato fruits.

This research cannot be published as it lacks innovation and originality and offers no new knowledge to the field. There is a series of published research on the same topic (application of Aloe vera gel on tomato fruits), and a lot of them are not even referenced.

Response:

Thank you for the reviewer comments. References, especially research on A. vera and tomato fruits, have been added to the manuscript.

Additionally, the experimental design is poor (only 1 treatment tested), the methods described are unreferenced, and there is no statistical analysis to support the presented data.

Response:

Thank you for the reviewer comments. In our research, we also tested another treatment, as previously conducted by Chrysargyris et al. (2016), diluting the aloe vera gel. However, the result was not satisfying. Therefore, we decided to report the original no dilution A. vera gel in this manuscript.

In addition, some methods described were already referenced. The reviewer is correct that some methods, such as moisture content, weight loss, pH, total soluble solids, and color, were not referenced. We assumed that it is a routine or general procedure already well known to readers in our research field. We add references in the qualitative analysis of phytochemicals.

We apologize that we accidentally deleted the statistical analysis section as presented in the Figure and Table where we did the statistical analysis. Thank you for the correction. The statistical analysis section has been added to the manuscript.

Tomatoes are one of the fruits commodities that can be maintained in terms of quality during storage using edible coating. Aloe vera contains polysaccharide components that can be used as an ingredient for edible coating. Therefore, exploration about the usage of aloe vera as an ingredient of edible coating is needed. The author's study would be excellent finding for further utilization of aloe vera. However, it requires several improvements before it can be considered for publication.

Response:
Thank you very much for the suggestions. We believe that it will improve the quality of the manuscript

Abstract:

- Please add the conclusion about the organoleptic test

Response: Additional conclusion on organoleptic has been placed in the abstract lines 22-24 (highlight green)

From the organoleptic test, the non-coated tomato was preferred by the panelist for the color, but for the glossiness, skin appearance, and texture, the coated tomatoes were preferred

Keywords:

- Please add more keywords that different from manuscript title to enhance discoverability.

Response: Additional keyword has been placed line 27 (highlight green)

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

Materials and method:

- Please provide detailed information about aloe vera and tomatoes harvest time (month and year)

Response: Information has been added in the material section lines 96,103 (highlight green)

The tomato (cv. Ratna) was harvested 90 days after sowing in July 2021.

the *A. vera* was harvested at six months (July 2021),

- Please mention detailed information about chemical materials that used in this study

Response: Information has been added in the material section lines 105-107 (highlight green)

Moreover, the chemicals used for analysis (NaOH, phenolphthalein indicator, H_2SO_4, $FeCl_3$, Folin Ciocalteau, Na_2CO_3, gallic acid, $NaNO_2$, AlCl3, hexane, acetone, ethanol, DPPH, BHT, $FeSO_4.7H_2O$) were purchased from Merck, Germany, and Sigma Aldrich, Singapore, unless otherwise stated

- Temperature unit should be written separated from the value – 80 °C

Response:Thank you for your correction. Changes has been made throughout the manuscript

- Line 103: Please add information about heating method that used in this study

Response: Information has been added in the method of A vera gel preparation section lines 113-114 (highlight green)

heated in an iron cast pot using stove

- Line 149: Please add information about the method that used for organoleptic test

Response: Information has been added in the method of organoleptic test lines 163-165 (highlight green)

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.

- Inconsistent word: hours or h

Response: Changes has been made from hours to h throughout the manuscript

- Please use subscript for the number in chemicals name: H2SO4, FeCl3, Na2CO3

Response: Done throughout the manuscript

Result:

- Line 232: Why the initial moisture of tomato with coating and without coating was different? Did this study use the same sample for those two treatments? If the study used the same group of tomatoes, the moisture should have the same amount.

Response: Thank you for the reviewer's comment. In this research total of 150 tomatoes were used. We performed initial screening (described in the material section) to ensure the sample's homogeneity. We use 5 tomatoes for each treatment (coated and non-coated) and each day of storage observation. Furthermore, the treatment was repeated three times. The slight difference in initial moisture could be due to variations in natural resources. It is only observed in moisture content and was not the case for the other parameters.

- The written of significant figure should be standardized

Response: We apologize for not fully understanding the reviewer's comment on standardized. In the figures, we placed the standard deviation in every point based on the statistical analysis comparing two means (coated and non-coated)

Conclusion:

- Please add the conclusion about organoleptic test

Response: Information has been added in the conclusion lines 531-533 (highlight green)

From the organoleptic test, the non-coated tomato was preferred by the panelist for the color, but for the glossiness, skin appearance, and texture, the coated tomatoes were preferred

This manuscript is globally well written with a great review of the litterature and on the discussion, but requires the completion of the material and methods and a better description of the results, in the results part we mainly find discussion, results are not described. Besides the results are not supported by a statistical analysis.

More detailed comments can be found in the document attached

coatings

Article

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 aloe vera gel can be used as an ingredient for edible films or coatings. The edible film can also be applied to fresh fruit and vegetables using the coating principle. Tomatoes are one of the fruits commodities that can be maintained in terms of quality during storage using the edible coating. This study aims to determine the effect of edible coating made from aloe vera on tomatoes' physical, chemical, and organoleptic properties during storage. The aloe vera gel was prepared and used for coating the tomato, and the tomato was 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 application of aloe vera could prolong the shelf life of tomatoes. In addition, Aloe vera edible coating decreases moisture content and weight loss. Furthermore, the edible coating affects the titratable acidity, pH, and total soluble solids. Meanwhile, the coating process could retain the hardness of the tomato. Moreover, the degradation of phenolic and flavonoid compounds, inhibiting lycopene production and maintaining antioxidant activity, was observed.

Keywords: tomato, aloe vera, edible coating, storage

Citation: Lastname, F.; Lastname, F.; Lastname, F. Title. *Foods* **2022**, *11*, x. https://doi.org/10.3390/xxxxx

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1. Introduction

Aloe vera is a plant from the Liliaceae family extensively distributed in Middle East and Africa. This plant is widely grown in tropical and subtropical areas, including Indonesia, due to its resistance to dry conditions because of the ability to absorb water and store in a longer time, therefore equipped the plant with sufficient water to live in the drought and extreme dry condition [1]. Aloe 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 aloe vera, drinks, and snack mixes. However, the utilization of Aloe vera is limited to food products because it naturally tastes bitter when consumed [3].

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

The presence of polysaccharide components in aloe 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]. 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 or packaging of food products and at the same time can be directly consumed. The main goal of developing edible films or coatings is to create an environmental-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 product from damage. Moreover, the edible film and coating can also carry preservative agent, flavoring agent, and colorant to extend the shelf-life, enhance the flavor, and improve the appearance of food and food product [7]. Some food products that often found using edible packaging are candy, chocolate, sausage, dried fruit, and bakery products [8].

The edible film can also be applied to fresh fruit and vegetables using the coating principle. Enormous percentage of postharvest losses especially for fruit and vegetables has been major challenges in the developing countries to ensure the food security status. In contrast to edible films that is 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 fruit and vegetables because it will decrease the contact to oxygen, respiration rate, and generally affect the metabolism of fruits and vegetables, thereby preventing the spoilage of fruits [9]. In addition, the presence of 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 [10]. Due to its 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 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

Tomatoes are one of the fruits commodities that can be maintained in terms of quality during storage using the edible coating. Tomato, as a climacteric fruit, is susceptible to post-harvest damage. 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 of respiration rate and the growth of microbes, thus accelerating spoilage. Research on the application of edible coatings on tomatoes has been reported [11], generally using various starch and hydrocolloids. However, limited research is available on the edible coatings made from aloe vera to maintain the physical, chemical, and organoleptic qualities of tomato during storage. Therefore, this study aims to determine the effect of edible coating made from aloe vera on tomatoes' physical, chemical, and organoleptic properties during storage.

2. Materials and Methods

Aloe vera was grown in Madiun District, East Java and purchased through a national aloe vera supplier in Sidoarjo District, East Java Province, Indonesia. Meanwhile, the tomato was obtained from local farmers in Malang District, East Java Province. The tomato was harvested after 90 days. The tomato was chosen within the turning level of maturity specified by the range of yellow, light red, and red colors of approximately 10-30%. The average diameter of a tomato is 2.5±0.25 cm, weight 20±2 g for each tomato, has a slightly acidic taste, and the absence of injury. Meanwhile, the aloe vera was harvested at six months, possesses a clean green skin color, is approximately 45±4.5 cm long, weighs around 350±35 g for each rind, and has the absence of injury on the surface of the rind. Moreover, all the chemical used for analysis was purchased from Merck, Germany, and Sigma Aldrich, Singapore, unless otherwise stated

2.1. Preparation of aloe vera coating gel and coating process

The aloe vera rind was washed to remove the impurities. Then, 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 at 80°C for 5 min. After heating, the aloe vera gel was allowed to cool to room temperature. Meanwhile, the tomato was washed to remove the impurities, soaked in the aloe vera gel for 5 min, and placed in an open tray at room temperature to let the aloe 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 hours. After that, the sample was cooled in a desiccator for 10 minutes before weighing. Repeat the step until the constant weight of the sample was achieved. Finally, the sample's moisture content is 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 tomato was measured at the beginning of the experiment (day 0) after the air drying. Then, the sample was weighed every three 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 [12]. Briefly, the sample was crushed. Then, 10 g of sample was placed in a 100 mL volumetric flask and filled with distilled water. After that, the sample solution was filtered using Whatman no 42 filter paper. Then, 10 mL of sample were placed in Erlenmeyer, 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.

2.5. pH

The pH was examined using a pH meter. First, the sample was blended and filtered. Then, 100 mL of filtrate was placed in a glass beaker. Before the measurement process, the pH meter was calibrated using buffer pH 4.0 and 7.0. Next, the electrode was simmered in the sample until the stabile pH value was observed.

2.6. Total Soluble Solid

The total soluble solid of tomato was determined using refractometer. In brief, the sample was blended and filtered using a clean cloth. Then, the filtrate was collected. Finally, three drops of the sample were placed in the refractometer prism, which was cleaned beforehand using distilled water and lens paper, and the measurement was performed.

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) [13]. 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.

2.9. Organoleptic test

The organoleptic test was performed to determine sensory properties of tomato preferred by the panelist. The quality parameter 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 tomato after storage. A total of 120 semi-trained panelists participated in the organoleptic test.

2.10. Extraction of tomato

A 250 g of tomato was sliced and blended for 30 seconds. Then 250 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 hours. 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 distilled water for analysis.

2.11. Qualitative analysis

a. Alkaloids

In brief, 1 mL of extract was placed in a test tube. Then 1 mL chloroform containing one drop of ammonia and five drops of 5M H2SO4 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.

b. Saponin and Tannin

Prepare two test tubes with 3 mL of extract added for each tube. For the saponin test, the test tube was vertically sonicated for 10 seconds 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 FeCl3 solution was added. If the sample contains tannin, the solution will turn to dark blue color.

c. Cardiac glycoside

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.

2.12. Total phenolic content

The phenolic compound was measured according to [14]. 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 minutes. After that, 2 mL 2.5% Na2CO3 and 4 mL of distilled water were added to the mixture, immediately vortexed, and stored in a dark place for 30 minutes. 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 [15]. A 0.5 mL of extract was mixed with 0.3, 0.3, and 2mL of 5% NaNO2, 10% AlCl3, and 1M 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.

2.14. Lycopene content

The lycopene content of the sample was measured spectrophotometrically [16]. In brief, the fresh tomato was 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 minutes. 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.

2.15. Antioxidant activity

a. DPPH method

The capacity of extract in scavenge DPPH radical was determined according to [17]. 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 [14]. 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] (FeSO4.7H2O, 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.

3. Results and Discussion

Tomato is a food commodity widely used in processed food or consumed in fresh-cut form. During storage, the quality of tomatoes can quickly decrease due to continuous respiration. Tomato belongs to the climacteric fruit group, which is the fruit that experiences a dramatic increase in respiration rate during ripening, including after being harvested [18]. The respiration produces energy that the tomato can use to carry out metabolic processes in the ripening stage to reach the fully matured tomato and leads to the senescence stage. The average shelf life of fresh-cut tomatoes stored at room temperature is approximately seven days [19]. Providing edible coating as the outer layer of tomato could potentially prolong the shelf life of tomato.

The moisture content of fruit is essential in affecting the fruit's freshness, appearance, and texture [20]. 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 Aloe vera gel had an initial moisture content of 95.11±0.04%, and after being stored for 12 days, the moisture content of tomato fruit became 94.24±0.29%. The result shows that the decrease in moisture content of non-coated tomatoes is higher than that of coated tomatoes. Therefore, the Aloe vera gel was shown as an effective coating agent in maintaining the moisture content of tomatoes during storage.

The decrease of moisture content in tomatoes was caused by the respiration and transpiration processes during storage. The water content of fruit will reduce during storage caused of the transpiration process, which evaporates water in the fruit tissue [21]. A thin coating layer of Aloe vera gel on the surface of tomatoes can inhibit exposure of fruit to oxygen, thus delaying the respiration process. In addition, the Aloe 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 [22]. 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 [23]. Meanwhile, Allegra et al. [24], who applied Aloe vera gel as an edible coating on fig fruit which is also climacteric fruit, suggested a significant decrease in moisture content during storage. Therefore, the presence of edible coating could lower the reduction rate of moisture content. Moreover, Mendy et al. [25] worked on papaya fruit stored at room temperature. A smaller decrease was observed on papaya coated with aloe 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 of moisture content could negatively influence the sensory properties of tomatoes, especially their fresh appearance [26]. 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 than coated tomatoes (Figure 1B). Furthermore, a significant difference was observed in applying the edible coating to the weight loss percentage of tomatoes during storage. According to Tzortzakis et al. [27], tomato fruit weight loss tends to increase during storage. Tomato can experience weight loss during storage because of the water evaporation due to respiration and transpiration processes. Aloe 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 [28]. 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.

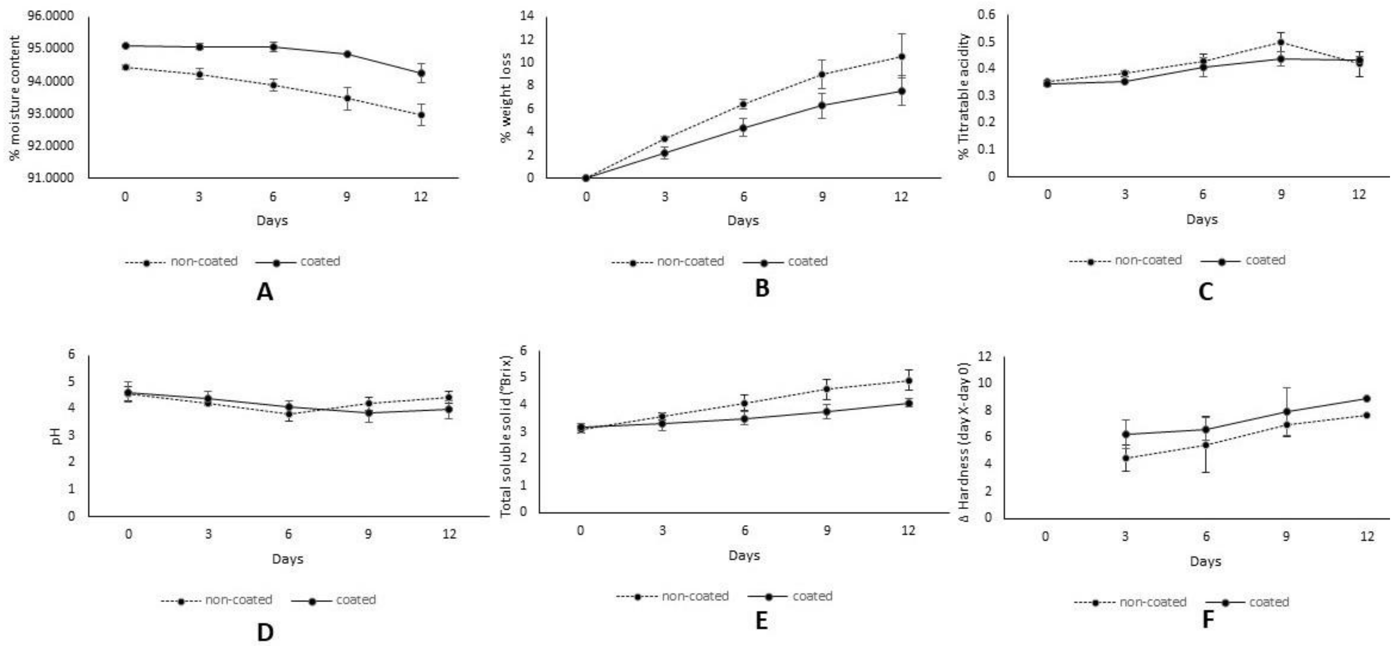

Figure 1. The effect of aloe vera edible coating on (A) moisture content, (B) weight loss, (C) titratable acidity, (D) pH, (E) total soluble solid, and (F) hardness of tomatoes

Figure 1C illustrates the change in total titratable acidity of coated and non-coated tomatoes during storage. An increase in titratable acidity was observed until the ninth day of storage. After nine days, the titratable acidity was decreased. Meanwhile, on the 12th day, the non-coated tomatoes experienced a higher decrease than the coated tomatoes. 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 climacteric fruit, during storage, the respiration rate of the tomato is increasing, which influences the titratable acidity [29]. After certain 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 Aloe vera gel can reduce the fruit's respiration rate because it minimizes tomatoes' exposure to O_2. Aloe 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, ripening stage, and inhibiting senescence [30].

The pattern of pH change in coated and non-coated tomatoes is shown in Figure 1D. According to Mohammadi et al. [31], 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. [32] 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.

The total soluble solids (TSS) determination could 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 with the coated tomatoes and was found to be lower. 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 [33]. Therefore, the higher the maturity level of the tomatoes, the higher the TSS value, which means that the tomatoes are getting sweeter. On the other hand, the Aloe 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 decrease the hydrolysis of polysaccharide into soluble solid [34].

Meanwhile, the result of the hardness of the tomato is presented in Figure 1F. Both treatments show a decrease in hardness during storage. The longer storage time resulted in the continuous decrease of 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. Moreover, the metabolism of tomatoes can degrade the pectin as a substance responsible for wall integrity of fruit into more minor water-soluble compounds with the help of enzymes polygalacturonases and pectinmethylesterases resulting in the texture softening of the fruit wall [35]. The non-coated treatment had a higher hardness decrease due to the tomatoes' metabolism. The aloe vera coating agent inhibits the metabolism process, significantly reducing the work of enzyme-converting protopectin into water-soluble pectin. Esmaeili et al. [36] reported that strawberry coated with aloe 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 result is presented in Table 1. The Lightness result shows a decrease in the coated and non-coated tomatoes due to the increase in the ripeness. This result is supported by 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 [37]. Meanwhile, the redness result (a*) shows an increase in the tomato's redness value during storage, with the uncoated tomato having a higher redness value than the coated tomato. It can be concluded that the changes of color in uncoated tomatoes are faster. The presence of edible coating can inhibit the formation of redness in tomatoes. Fruit coating could reduce the ethylene formation rate, thus delaying the maturity, chlorophyll degradation, anthocyanin accumulation, and carotenoid synthesis. The color changes of 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 [38]. Previous research observed that aloe vera gel as a coating agent of mango could inhibit the chlorophyll degradation, thus delaying the red color formation [39]. In contrast with the redness, the yellowness of tomato (b*) declined in both treatments. The non-coated tomato shows a higher yellowness decrease than the coated group. The edible coating could inhibit the yellowness formation of tomato. The metabolic process of tomato 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 tomato was decreased for both treatments. The edible coating significantly inhibits the respiration and transpiration rate of tomatoes, thus minimizing color changes.

A similar trend was observed for chroma value. Aghdam et al. [40] observed a decrease in chroma during storage.

Table 1. Colour changes of tomato during storage

Parameters	Treatment	Δ colour (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	[illegible].2±0.7	5.3±0.48	14.8±1.1	16.5±1.1
Redness	Coated	1.23±0.61	2.57±0.67	3.69±0.79	4.23±0.46
	Non-Coated	3.1±0.7	5.1±1.0	6.3±1.2	6.7±0.5
Yellowness	Coated	2.46±0.91	4.42±1.23	5.31±0.80	6.68±0.76
	Non-Coated	6.5±0.8	9.8±1.2	14.0±1.8	15.9±1.3
Hue	Coated	2.07±0.4	4.23±0.37	5.83±0.69	7.43±0.8
	Non-Coated	4.9±1.0	8.4±1.4	11.7±1.9	13.1±0.6
Chroma	Coated	2.02±1.03	3.46±1.33	3.92±0.96	4.85±1.02
	Non-Coated	5.8±0.7	8.4±1.1	12.0±1.6	13.7±1.3

In this research, the organoleptic test was also performed. The result in Table 2. shows that on day 9, the non-coated tomato was preferred by the panelist for the color because it has a more intense red color than the coated tomato. The presence of edible coating could inhibit the maturity stage, thus preventing the red color formation of tomato. Meanwhile, for appearance, glossy, and texture, the coated tomato was chosen by the panelist because it could delay the shrinkage of the fruit wall and thus create a pleasant overall appearance of the tomato. At the same time, applying an edible coating could create a glossy surface for fruit [41]. Furthermore, the inhibition of tomato metabolism by edible coating could retain the rigid texture of tomato preferred by the panelist.

Table 2. Organoleptic properties of tomato stored for 9 days

Parameters	Treatment	Score
Color	Coated	3.64
	Non-Coated	4.44
Skin appearance	Coated	2.71
	Non-Coated	1.54
Glossy	Coated	2.88
	Non-Coated	2.19
Texture	Coated	3.05
	Non-Coated	1.98

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. In this research, the bioactive compound of coated and non-coated tomatoes, which were stored for twelve days, was quantified and examined for their antioxidant capacity. Identification of phytochemical compounds is performed qualitatively before the quantitative analysis. Several studies have stated that phytochemical compounds contained in tomatoes include saponins, alkaloids, flavonoids, phenols, and carotenoids [42]. 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 tomato indicates a higher phytochemical content. 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 [43].

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 increase of phenolic content was observed on the third day and started to reduce on the sixth day of storage (Figure 3A). The decline of 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 [44]. Meanwhile, the rise in phenolic content 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 [45]. As a result, the total phenol of coated tomato was slightly lower than the non-coated group. This result is in line with a previous report by Riaz et al. [46], 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. Previous report suggested that the decrease of phenolic can also be due to the autoxidation reaction of phenol compounds by oxygen and light [47].

The individual flavonoid compounds of tomato include naringenin, the flavanone group, rutin, kaempferol and quercetin [48]. A similar pattern with phenolic content was observed in the flavonoid content of tomatoes (Figure 3B). 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 of flavonoid content during storage. Such functions are related to the capability as the barrier of the air and moisture from the environment [49].

Results in Figure 3C showed an increase in lycopene content during storage. During the ripening stage, lycopene content was increased due to degradation of chlorophyll and accumulation of lycopene in fruit [50]. Previous reports observed the increase of lycopene in stored tomatoes. During storage, the non-coated tomato exhibits a higher increase in lycopene content than the coated group and the delay of color change in aloe vera-coated fruit. The application of Aloe vera as a coating agent prevents the degradation of chlorophyll and the accumulation of lycopene in the ripening stage. In addition, the aloe vera coating act as a barrier to air and moisture, thus decreasing the respiration rate of fruit [51,52].

Furthermore, the antioxidant activity of tomatoes was examined using DPPH and FRAP methods. The result shows that the tomato extract can scavenge DPPH radical

(Figure 3D). A positive correlation 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 [53]. However, after the third day of storage, the antioxidant activity of the tomato declined. The result is also in line with the decrease in phenolic content. In addition to the lower phenolic compound content, the decrease of 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 methods (Figure 3E). 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 [54].

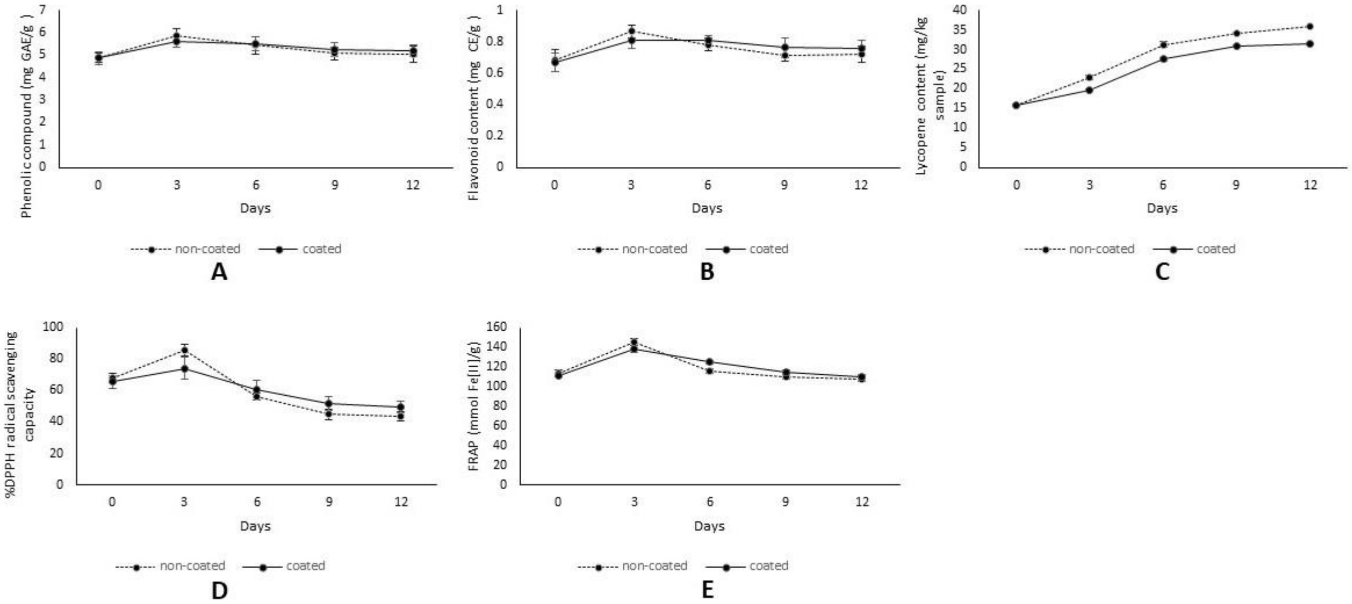

Figure 2. The effect of aloe vera coating on (A) phenolic content, (B) flavonoid content, (C) lycopene content, (D) DPPH radical scavenging capacity, and (E) Ferric Reducing Antioxidant Power of tomatoes

4. Conclusion

The application of aloe vera gel edible coating could prolong the shelf life of tomatoes, as observed from the color measurement and organoleptic test. In addition, Aloe 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. Moreover, the presence of aloe 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.

Supplementary Materials: -

Author Contributions: Conceptualization, A.R.U., E.S., I.R.A.P.J.; methodology, I.R.A.P.J., A.R.U., E.S.; software, L.M.Y.D.D.; formal analysis, I.R.A.P.J., A.R.U., E.S.; resources, I.R.A.P.J., L.M.Y.D.D.; writing—original draft preparation, I.R.A.P.J., A.R.U., E.S.; writing—review and editing, A.R.U., E.S., I.R.A.P.J; visualization, L.M.Y.D.D.; supervision, A.R.U.; project administration, E.S.; funding acquisition, I.R.A.P.J. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: data is available upon request

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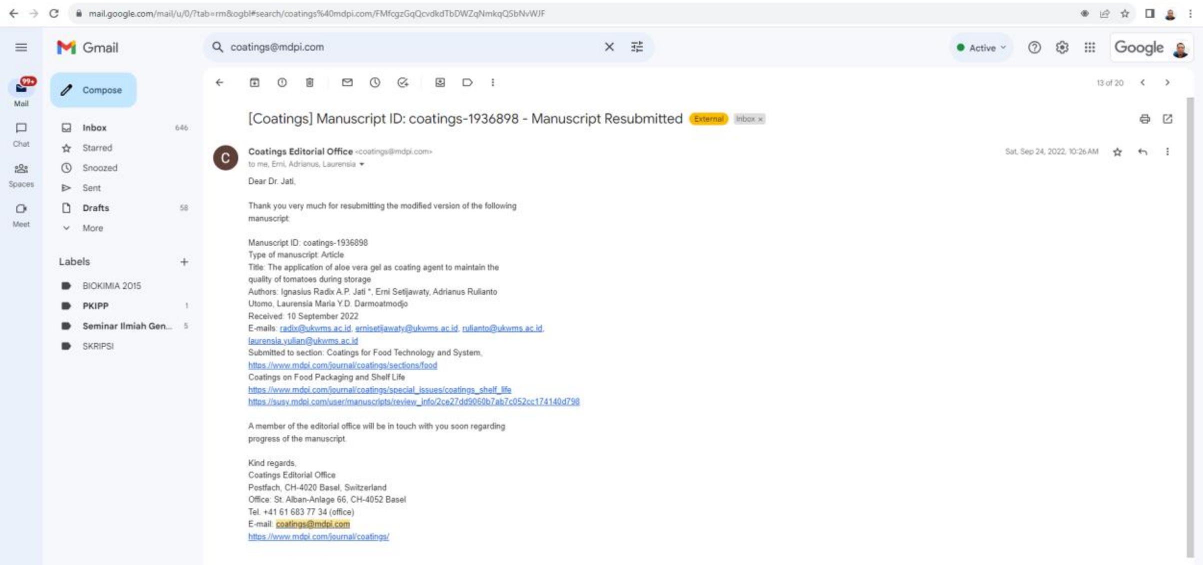

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The application of *Aloe vera* gel as coating agent to maintain the quality of tomatoes during storage

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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 an ingredient for edible films or coatings. The edible film can also be applied to fresh fruit and vegetables using the coating principle. Tomatoes are one of the fruits commodities that can be maintained in terms of quality during storage using an edible coating. This study aims to determine the effect of 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 tomato, and the tomato was 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 solids contents than the non-coated tomatoes. From the organoleptic test, the non-coated tomato was preferred by the panelist for the color, but for the glossiness, skin appearance, and texture, the coated tomatoes were preferred. While the coating process could maintain the hardness of tomatoes and prevent the production of phenolic, 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 of 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]. 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 or packaging of 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 environmental-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 product from damage [8]. Moreover, the edible film and coating can also carry preservative agent, flavoring agent, and colorant to extend the shelf-life, enhance the flavor, and improve the appearance of food and food product [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 fruit and vegetables using the coating principle. Enormous percentage of postharvest losses especially for fruit and vegetables has been major challenges in the developing countries to ensure the food security status [11]. In contrast to edible films that is 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 fruit and vegetables because it will decrease the contact to oxygen, respiration rate, and generally affect the metabolism of fruits and vegetables, thereby preventing the spoilage of fruits [12]. In addition, the presence of 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 its 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 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 fruits commodities that can be maintained in terms of quality during storage using the edible coating. Tomato, as a climacteric fruit, is susceptible to post-harvest 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 of 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. Mean-while tomatoes which are stored at room temperature (25 °C), undergo a rapid quality decrease on the 5th 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 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 tomato was obtained from local farmers in Malang District, East Java Province. The tomato (cv. Ratna) was harvested 90 days after sowing in July 2021. A total of 150 tomatoes was selected, 5 tomatoes for each coating and non-coating treatment and for three replications. The tomato was 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 a tomato is 2.5±0.25 cm, weight 20±2 g for each tomato, has a slightly acidic taste, and the absence of injury. Meanwhile, the *A. vera* was harvested at six months (July 2021), possesses a clean green skin color, is approximately 45±4.5 cm long, weighs around 350±35 g for each rind, and has 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, $NaNO_2$, AlCl3, hexane, acetone, ethanol, DPPH, BHT, $FeSO_4.7H_2O$) were purchased from Merck, 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, 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 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 minutes before weighing. Repeat the step until the constant weight of the sample was achieved. Finally, the sample's moisture content is 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 three 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 were placed in Erlenmeyer, 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. 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 stabile pH value was observed.

2.6. Total Soluble Solid

The total soluble solid of tomato was determined using 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) [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 panelist. The quality parameter 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 of tomato was sliced and blended for 30 seconds. 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 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 phytochemical 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 chloroform containing one drop of ammonia and five drops of 5M 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

Prepare two test tubes with 3 mL of extract added for each tube. For the saponin test, the test tube was vertically sonicated for 10 seconds 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 minutes. After that, 2 mL 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 minutes. 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]. A 0.5 mL of extract was mixed with 0.3, 0.3, and 2mL of 5% $NaNO_2$, 10% $AlCl_3$, and 1M 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 minutes. 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 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 was expressed as means ± SD. The student T test was performed to determine the significant difference of parameters between the coated and non-coated tomatoes. The analysis was performed using SPSS ver. 23 with statistical significance set at $P < 0.05$

3. Results and Discussion

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

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 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%). 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.

The decrease of moisture content in tomatoes was caused by the respiration and transpiration processes during storage. The water content of fruit will reduce during storage caused of 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 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 climacteric fruit, suggested a significant decrease in moisture content during storage. Therefore, the presence of 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 of 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.

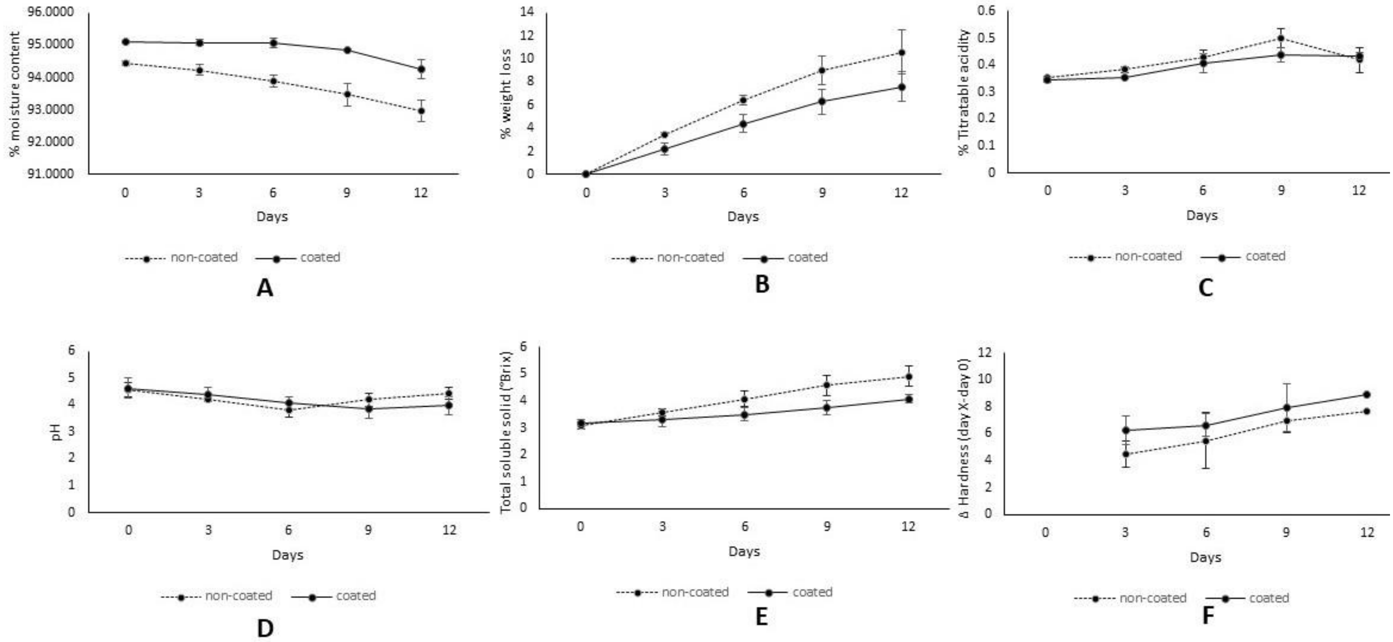

Figure 1. The effect of *A. vera* edible coating on (A) moisture content, (B) weight loss, (C) titratable acidity, (D) pH, (E) total soluble solid, and (F) hardness of tomatoes

Figure 1C illustrates the change in total titratable acidity of coated and non-coated tomatoes during storage. An increase trend in titratable acidity was observed until the ninth day of storage, which were 0.34% to 0.43% for coated group and 0.35%-0.49% for non-coated group. After nine days, the titratable acidity was decreased into 0.43% and 0.41% for coated and non-coated tomatoes respectively. Even though, on the 12th day, the non-coated tomatoes experienced a higher decrease than the coated tomatoes, however there were 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 climacteric fruit, during storage, the respiration rate of the tomato is increasing, which influences the titratable acidity [37]. After certain 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, 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 was decreased from 4.56 to 3.39 on day 0 and 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 of 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 could 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 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 on 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 are getting 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 decrease the hydrolysis of polysaccharide into soluble solid [43].

Meanwhile, the result of the hardness of the tomato is presented in Figure 1F. Both treatments show a decrease in hardness during storage. The data presented the difference between hardness in days of storage with initial hardness (day 0). For coated tomatoes, the difference on day 3 and day 12 was 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 of 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 as a substance responsible for wall integrity of fruit into more minor water-soluble compounds with the help of 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 strawberry coated 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 result is 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 is 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 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 tomato's redness value during storage, with the uncoated tomato having a higher redness value than the coated tomato. It can be concluded that the changes of color in uncoated tomatoes are faster. The presence of edible coating can inhibit the formation of redness in tomatoes. Fruit coating could reduce the ethylene formation rate, thus delaying the maturity, chlorophyll degradation, anthocyanin accumulation, and carotenoid synthesis [36]. The color changes of 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 tomato (b*) declined in both treatments. The non-coated tomato shows 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 yellowness value was larger, with 6.51 for day 3 and 15.94 for day 12. The non-coated tomato shows a higher yellowness decrease than the coated group. The edible coating could inhibit the yellowness formation of tomato. The metabolic process of tomato 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 tomato was decreased for both treatments. The edible coating significantly inhibits 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 of tomato during storage

Parameters	Treatment	Δ colour (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 result in Table 2. shows that on day 9, the non-coated tomato was preferred by the panelist for the color because it has a more intense red color than the coated tomato. The presence of edible coating could inhibit the maturity stage, thus preventing the red color formation of tomato. Meanwhile, for appearance, glossy, and texture, the coated tomato was chosen by the panelist because it could delay the shrinkage of the fruit wall and thus create a pleasant overall appearance of the tomato. At the same time, applying an edible coating could create a glossy surface for fruit [52]. Furthermore, the inhibition of tomato metabolism by edible coating could retain the rigid texture of tomato preferred by the panelist.

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 their antioxidant capacity. Identification of phytochemical compounds is 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 tomato indicates a higher phytochemical content. 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 phytochemical and reducing sugar in the sample

The increase of 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, however, there was no significant difference found. The decline of 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 content 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 coated tomato 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. Previous report suggested that the decrease of phenolic 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 tomato 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 of flavonoid content during storage. Such functions are related to the capability as the barrier of the air and moisture from the environment [61].

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 of lycopene in stored tomatoes. During storage, the non-coated tomato exhibits a higher increase in lycopene content than the coated group and the delay of color change in *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 radical (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 tomato declined. The result is also in line with the decrease in phenolic content. In addition to the lower phenolic compound content, the decrease of 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 methods (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].

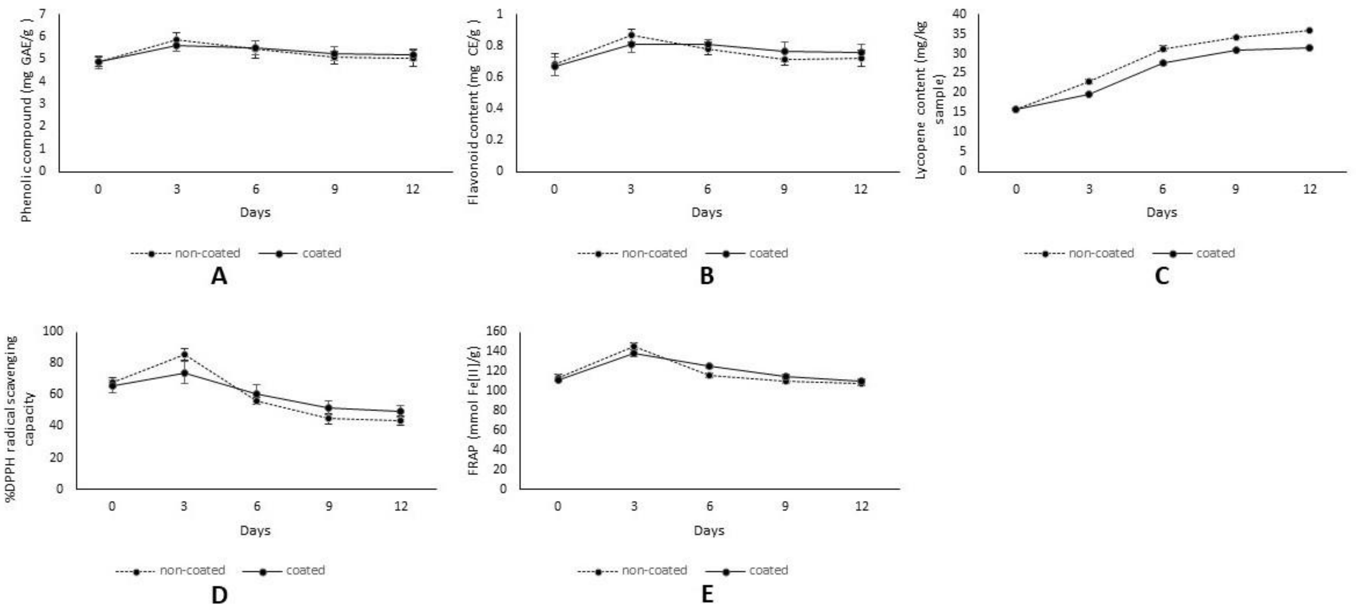

Figure 2. The effect of *A. vera* coating on (A) phenolic content, (B) flavonoid content, (C) lycopene content, (D) DPPH radical scavenging capacity, and (E) Ferric Reducing Antioxidant Power of tomatoes

4. Conclusion

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, *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 tomato was preferred by the panelist 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 the 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.

Supplementary Materials: -

Author Contributions: Conceptualization, A.R.U., E.S., I.R.A.P.J.; methodology, I.R.A.P.J., A.R.U., E.S.; software, L.M.Y.D.D.; formal analysis, I.R.A.P.J., A.R.U., E.S.; resources, I.R.A.P.J., L.M.Y.D.D.; writing—original draft preparation, I.R.A.P.J., A.R.U., E.S.; writing—review and editing, A.R.U., E.S., I.R.A.P.J; visualization, L.M.Y.D.D.; supervision, A.R.U.; project administration, E.S.; funding acquisition, I.R.A.P.J. All authors have read and agreed to the published version of the manuscript.

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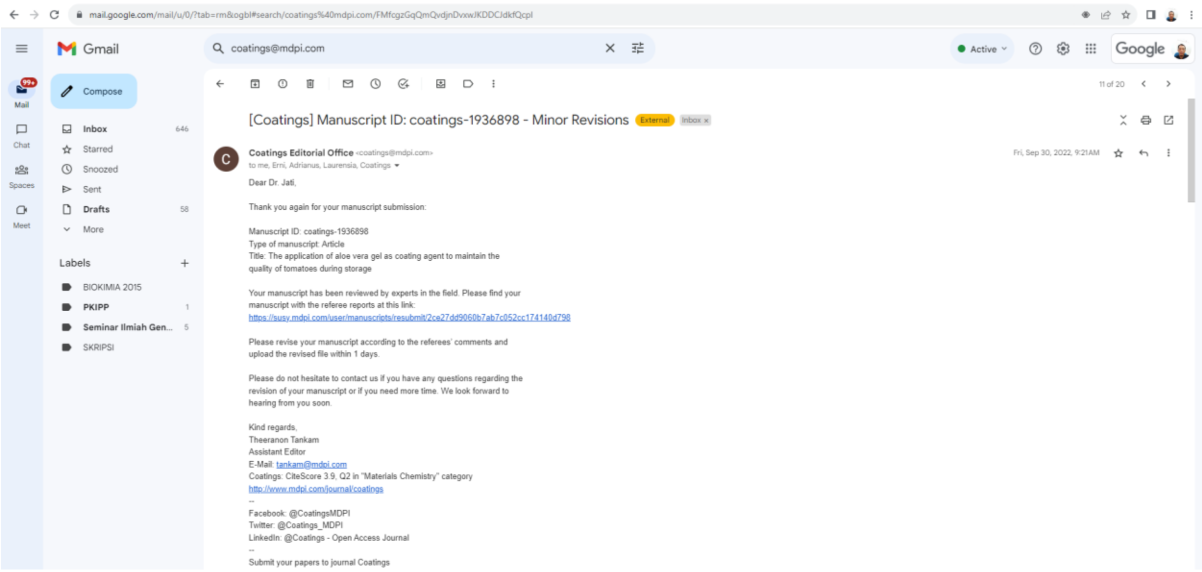

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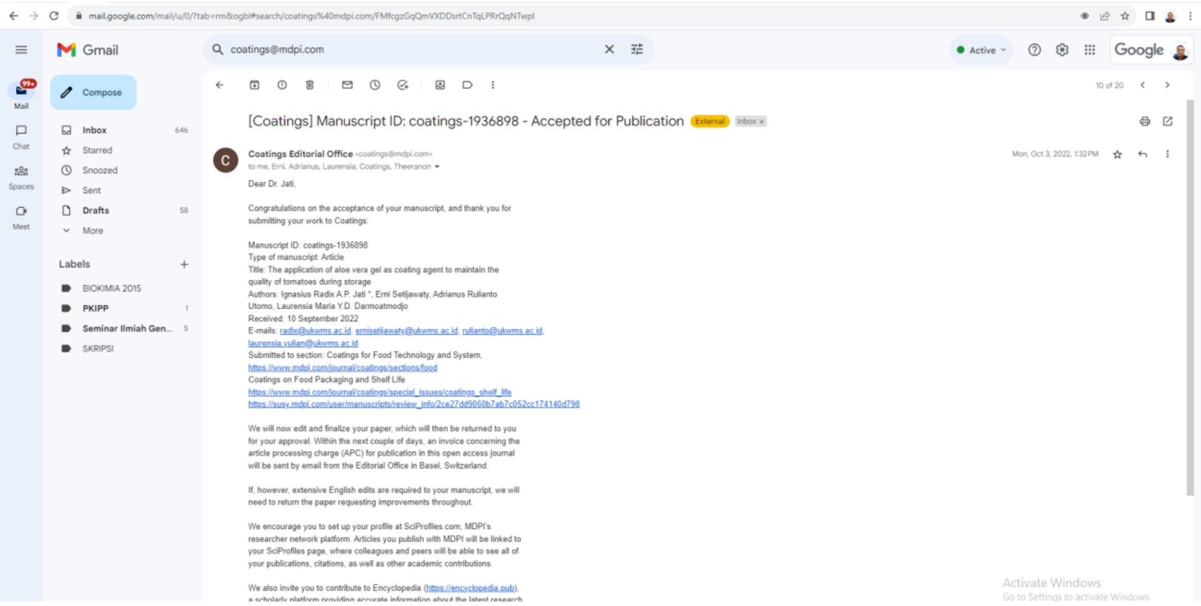

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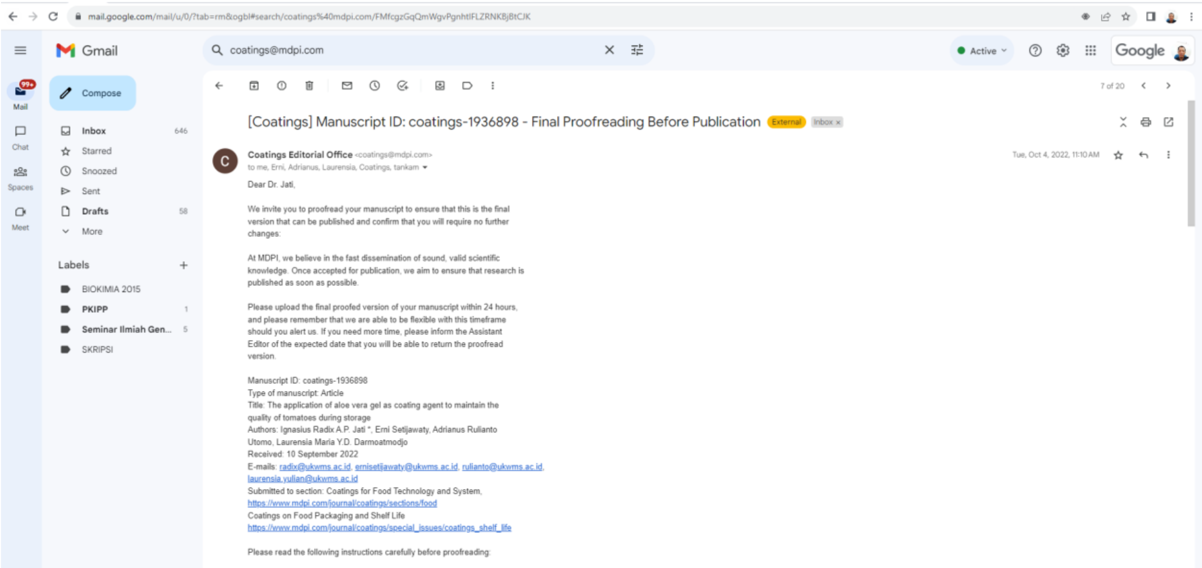

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The Application of *Aloe vera* Gel as Coating Agent to Maintain the Quality of Tomatoes during Storage

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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 ~~an~~ 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~~s~~ 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 ~~was~~ 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~~s~~ contents than the non-coated tomatoes. From the organoleptic test, the non-coated tomatoes ~~was~~ were preferred by the panelists for ~~the~~ color, but ~~for~~ the glossiness, skin appearance, and texture of ~~,~~ the coated tomatoes were preferred. ~~While t~~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 ~~of~~ 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]. ~~Edible~~ An edible film or

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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 ~~of~~ 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. ~~Enormous~~ An enormous percentage of postharvest losses, especially for fruits and vegetables, ~~has been~~is a major challenge~~s~~ in ~~the~~ developing countries to ensuring~~e~~ ~~the~~ food security status [11]. In contrast to edible films that ~~is~~ 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 ~~will~~ decreases the contact ~~to~~ 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 ~~its~~ 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~~s~~ commodities that can be maintained in terms of quality during storage using the edible coating. Tomato, as a climacteric fruit, is susceptible to post~~-~~harvest 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 ~~of~~ 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. Mean~~-~~while, tomatoes which are stored at room temperature (25 °C)~~,~~ undergo a rapid quality decrease on the ~~5th~~ 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 wereas~~as~~ obtained from local farmers in Malang District, East Java Province. The tomatoes (cv. Ratna) ~~was~~ were harvested 90 days after sowing in July 2021. A total of 150 tomatoes ~~was~~ were selected, 5 tomatoes for each coating and non-coating treatment and for ~~three~~ 3 replications. The tomato ~~was~~es 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 ~~a~~ tomatoes ~~is~~ was 2.5 ± 0.25 cm, weight 20 ± 2 g for each tomato, and they hads ~~ds~~ a slightly acidic taste with~~, and~~ the absence of injury. Meanwhile, the *A. vera* was harvested at six months (July 2021), possesseds ~~ds~~ a clean green skin color, was~~is~~ approximately 45 ± 4.5 cm long, weigheds ~~ds~~ around 350 ± 35 g for each rind, and hads ~~ds~~ 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, Germany, and Sigma Aldrich, Singapore, unless otherwise stated.

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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. ~~Repeat the~~This step was repeated until the constant weight of the sample was achieved. Finally, the sample's moisture content ~~is~~ 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~~three~~ 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 ~~were~~ 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 stab~~i~~le 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 lLightness (L*), redness (a*), yellowness (b*), hue (°h), and cChroma (C).

2.8. Hardness

The hardness of the tomato was measured using texture profile analyzer equipment (TA-XT Plus) [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).

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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

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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 5M 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].

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b. Saponin and Tannin

~~Prepare t~~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 1M 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~~ catechin e~~E~~quivalent/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 mix-

Commented [M711]: We changed en dash to minus sign, please confirm ture 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 ~~was~~ were expressed as means ± SD. The ~~S~~Student's T test was performed to determine the significant differences ~~in~~ ~~of~~ in parameters between the coated and non-coated tomatoes. The analysis was performed using SPSS v23 with statistical significance set at $p < 0.05$.

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3. Results and Discussion

~~The r~~Respiration produces energy that the tomato can use to carry out metabolic processes in the ripening stage to reach the fully matured ~~tomato~~ 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%). ~~Statistical~~ 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.

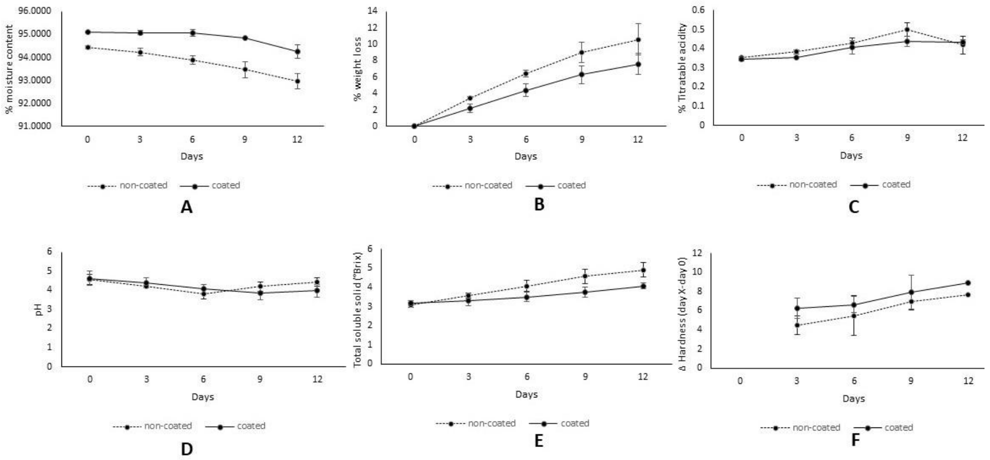

Figure 1. The effect of *A. vera* edible coating on (**A**) moisture content, (**B**) weight loss, (**C**) titratable acidity, (**D**) pH, (**E**) total soluble solid, and (**F**) hardness of tomatoes.

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The decrease ~~of~~ 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 ~~of~~ 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 ~~of~~ 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~~were~~ 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 ~~in~~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, ~~however~~ there ~~were~~ 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 ~~was~~ decreased from 4.56 to 3.39 ~~on~~ from day 0 ~~and~~ 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~~of~~ 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 ~~could~~ 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 ~~on~~ 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 ~~are getting~~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~~ed~~ the difference between hardness in days of storage with initial hardness (day 0). For coated tomatoes, the differences on day 3 and day 12 ~~was~~ 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~~of~~ 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~~ as~~, 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~~y~~ ~~coated~~ 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~~lightness, redness, yellowness, h~~H~~ue, and chroma were determined, and the result~~ is~~s are presented in Table 1. The l~~L~~ightness result shows a decrease in the coated and non-coated tomatoes due to the increase in the ripeness. The ~~data~~data are~~ is~~ 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 tomatoe~~'~~s redness value during storage, with the uncoated tomatoes having a higher redness value than the coated tomatoes. It can be concluded that the changes ~~of~~ in color in uncoated tomatoes are faster. The presence of an edible coating can inhibit the formation of redness in tomatoes. Fruit coating~~ could~~s can reduce the ethylene formation rate, thus delaying the maturity, chlorophyll degradation, anthocyanin accumulation, and carotenoid synthesis [36]. The color changes in~~of~~ 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~~s~~ 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~~s~~ 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 ~~inhibits~~ 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~~of~~ tomato during storage.

Parameters	Treatment	Δ Colo~~u~~r (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~~s~~ that on day 9, the non-coated tomatoes ~~was~~ were preferred by the panelists for the color because ~~it~~ they ha~~d~~s 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~~y~~, and texture, the coated tomatoes ~~was~~ were chosen by the panelists because ~~it~~ 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

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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~~their~~ antioxidant capacity. Identification of phytochemical compounds was~~is~~ 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~~s~~ ~~a~~ 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 ~~of~~ 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, ~~however,~~ there was no significant difference found. The decline ~~of~~ 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. ~~Previous~~ A previous report suggested that the decrease ~~of~~ in phenolic compounds can also be due to the autoxidation reaction of phenol compounds by oxygen and light [59].

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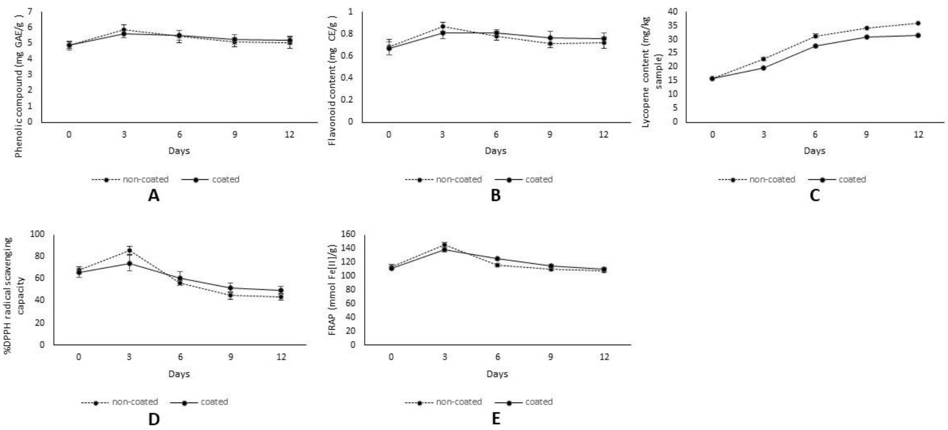

Figure 2. The effect of *A. vera* coating on (**A**) phenolic content, (**B**) flavonoid content, (**C**) lycopene content, (**D**) DPPH radical scavenging capacity, and ~~(E)~~(E) Ferric Reducing Antioxidant Power of tomatoes.

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 ~~of~~ in flavonoid content during storage. Such functions are related to the capability of the coating as the barrier ~~of~~ between the air and moisture from the environment [61].

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 ~~of~~ in lycopene in stored tomatoes. During storage, the non-coated tomatoes ~~exhibits~~ 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 pos-

Commented [M721]: We moved figure after first citation, please confirm sessed 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~~of~~ 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~~s~~ (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 tomato~~ was~~es 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.

Supplementary Materials:

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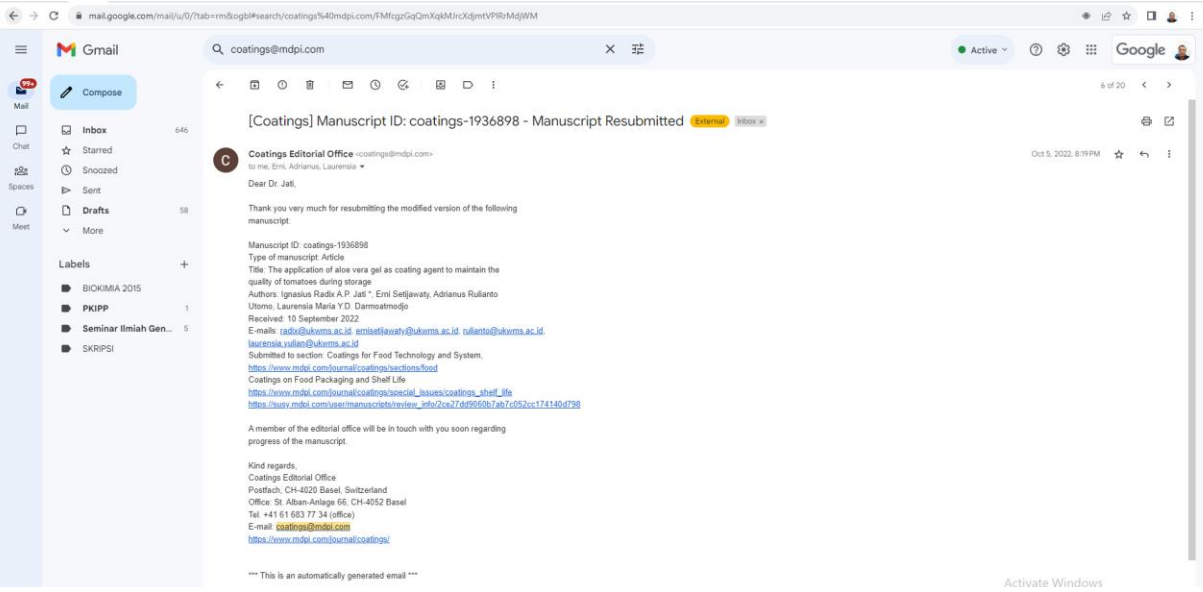

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The Application of *Aloe vera* Gel as Coating Agent to Maintain the Quality of Tomatoes during Storage

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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.

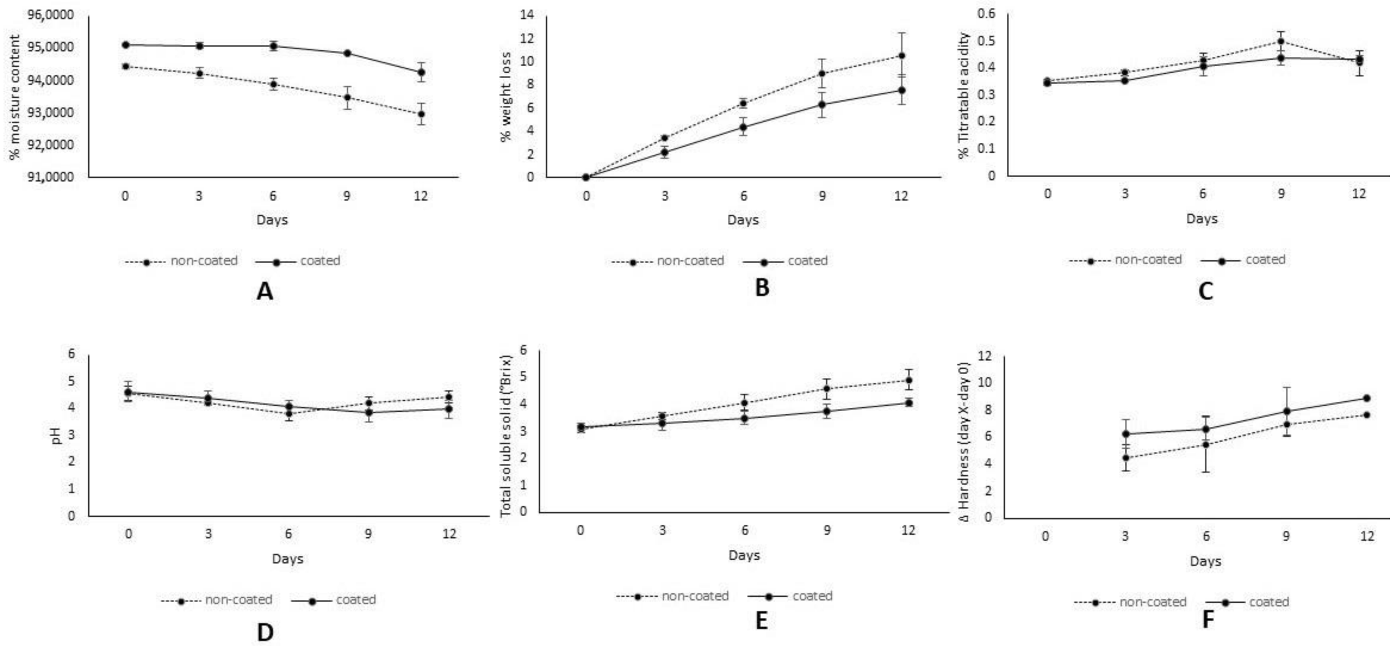

Figure 1. The effect of *A. vera* edible coating on (**A**) moisture content, (**B**) weight loss, (**C**) titratable acidity, (**D**) pH, (**E**) total soluble solid, and (**F**) hardness of tomatoes.

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].

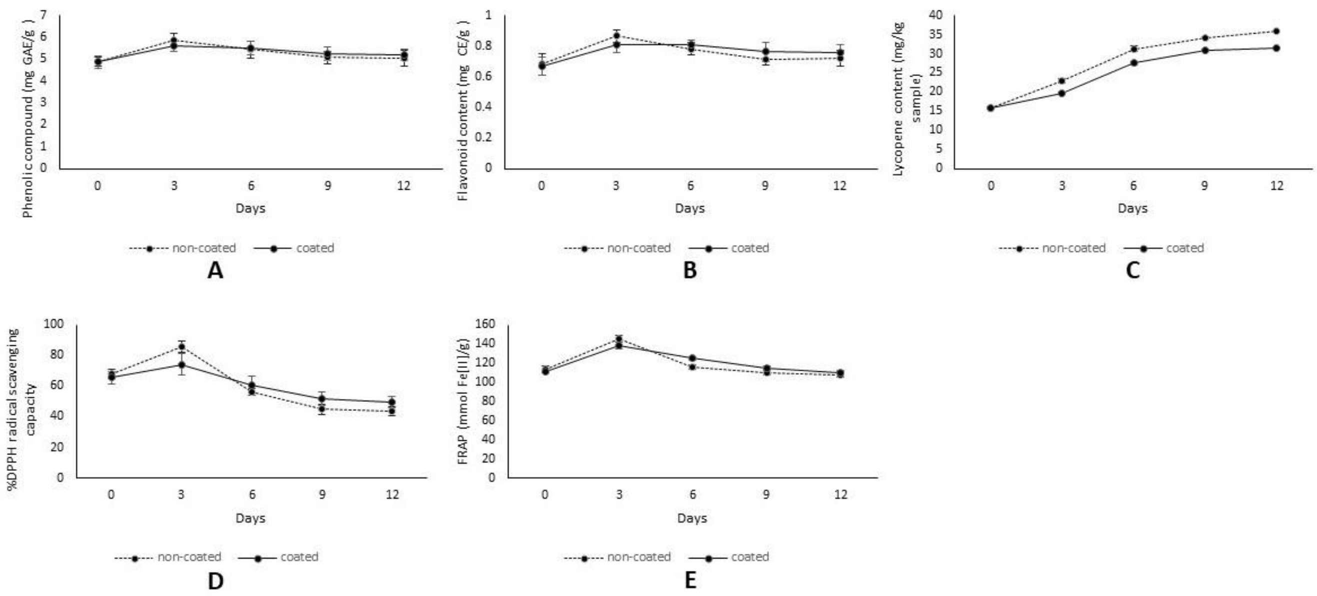

Figure 2. The effect of *A. vera* coating on (**A**) phenolic content, (**B**) flavonoid content, (**C**) lycopene content, (**D**) DPPH radical scavenging capacity, and (**E**) Ferric Reducing Antioxidant Power of tomatoes.

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].

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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