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Development of edible coating based on *Aloe vera* gel to extend the shelf life of fresh-cut melon

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KEYWORDS

Aloe vera gel

Carboxymethyl cellulose (CMC)

Edible coating

Fresh-cut melons

ABSTRACT

Edible coating has been widely used in the food and agriculture industry to maintain the quality of food, specifically fresh-cut fruits, and can extend the shelf life of fruits. In this research, *Aloe vera*-based edible coating was developed with the addition of carboxymethyl cellulose (CMC) and citric acid (CA) as additives to maintain the quality and extend the shelf life of fresh-cut melons (*Cucumis melo L*). Edible coating based on *Aloe vera* was made with 30% (v/v) and 50% (v/v) *Aloe vera* gel and mixed with 1% (w/v) and 3% (w/v) CMC as additives and 1% (w/v) citric acid. Fresh-cut melons were uncoated and coated with six combinations of *Aloe vera* and CMC concentrations, then stored for ten days at 30 °C. Weight loss, microbiological contamination, ascorbic acid content, titratable acidity, colorimeter analysis, and sensory analysis were evaluated every two days to assess the quality of fresh-cut melons. The findings indicated that the samples coated with 50% (v/v) *Aloe vera* gel and 3% (w/v) CMC had superior effectiveness and the highest quality in terms of weight loss, microbiological contamination, ascorbic acid content, titratable acidity, colorimeter analysis, and sensory evaluation.

Introduction

Edible coating has been known for its potential to extend the shelf life of foods, specifically fresh-cut fruits, because of its ability to create a barrier between the product and the environment (Xin et al., 2017). The coatings were thin layers made of raw materials formed directly on the surface of the fruit. They serve as a barrier against chemical, physical, and microbiological changes, and occasionally they contain additives that could lengthen the product's shelf life and increase its safety (Nicolau-Lapeña et al., 2021). Moreover, the edible coating can also maintain the quality of fresh-cut fruits by reducing microbial contamination, preventing the browning effect and shrinking effect, as well as by maintaining antioxidant, vitamin contents, and the firmness of fruits which can prevent the fruit senescence phase (Maringgal et al., 2020).

The most popular substance was polysaccharide because of its hydrophilic composition, which has a decent film-forming ability and can act as a barrier against gaseous exchange (Tavassoli et al., 2020). On the other hand, *Aloe vera*, is one of the accessible polysaccharides that contains cellulose in its gel, making it the ideal substance to be an edible coating base to preserve the quality of freshly cut fruits. It is also suitable for fruit coatings due to its transparent, odorless, and safe nature. *Aloe vera* has several beneficial bioactive substances that make it the best barrier to prevent microbial contamination, reduce respiration rate, and prevent fruit damage during storage (Hęś et al., 2019; Nicolau-Lapeña et al., 2021). These compounds include flavonoid, terpenoid, lectins, anthraquinone, mono- and polysaccharide, tannin, sterol, and salicy. However, *Aloe vera* gel lacks stability and uniformity in its composition because it mainly comprises 96% water (Passafiume et al., 2020; Zhang et al., 2018). As a result, it requires chemicals or emulsifiers to increase the gel's stability. Carboxymethyl cellulose (CMC) would be suitable because it has excellent biocompatibility, edibility, and stability. Additionally, once diluted, CMC has a clear hue that preserves the physical properties of its primary ingredient, *Aloe vera* gel (Joshy et al., 2020; Riaie et al., 2017).

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Fresh-cut fruit, especially melon, is susceptible to the rapid decline in quality once cut open. Some indicators that can be examined include a decline in firmness, vitamin C content, weight loss, flavor, aroma, and color, as well as an increase in microbial contamination that can result in a shorter shelf-life and the senescence phase (Maringgal et al., 2020). It is possible due to the melon's pronounced ethylene and respiration rates, high water content, and sugar content as one of the climacteric fruits (Madrid et al., 2004). However, melon is still one of the most popular fruits. It has high consumption levels for its sweet pulp and pleasant aroma and contains high levels of vitamins (A and C), folic acid, and beta-carotene (Sarengaowa et al., 2019). This research aimed to investigate the potential of *Aloe vera*-based edible coating to extend the shelf-life of fresh-cut melons by analyzing it through several parameters such as weight loss, ascorbic acid contents, titratable acidity, firmness, colorimeter analysis, microbial contamination, sugar content, and sensory analysis. The results of this research can be a promising solution and new insight for further research to investigate the potential of *Aloe vera*-based edible coating applied in fresh-cut fruits.

Research Methods

Materials

Fresh *Aloe vera* from local distributor Herbavera, Inc. (Indonesia) was used in this research. Carboxymethyl cellulose (CMC) and citric acid (CA) were purchased from PT. Merck Tbk. (Jakarta, Indonesia). Fresh melons were harvested from a local greenhouse, Laguna Greenhouse Farming (Central Java, Indonesia), and all chemicals used in this study were analytical grades.

Methods

a. *Preparation of Aloe vera gel and melons*

The preparation of *Aloe vera* gel was started by washing and soaking 2 kg of mature *Aloe vera* leaves in a chlorine solution (2 ppm) for 2 min to prevent the browning effect in the gel. The leaves were then peeled to extract the gel from the inner leaf and stored at a low temperature to make the edible coating. Melons were collected and selected based on their color, size, and shape similarity. Melons were then cleaned, peeled, separated from the seeds, and cut into identical-sized cubes (3x3 cm). About 250 g of fresh-cut melons was weighed and kept at room temperature (30 °C) in food containers. All samples were then reproduced three times (Ansar et al., 2020).

b. *Preparation of edible coating*

The prepared *Aloe vera* gel was mashed and filtered to obtain a decent gel consistency. The *Aloe vera* gel was then heated at 75 °C for 15 minutes using an IKA C-MAG H57 hotplate magnetic stirrer (IKA Co. Ltd., China) and cooled at room temperature (30 °C). Two concentrations of *Aloe vera* gel (i.e., 30% and 50%) were prepared. CMC (1% and 3%) and CA were added to each gel concentration, following a stirring and homogenization process (Riaie et al., 2017).

c. *Edible coating application on fresh-cut melon*

All samples of fresh-cut melons were dipped into the mixed coating solutions (Table 1) for 5 min and dried at room temperature for 1 min. After that, the samples were stored in food containers at room temperature for 10 days storage period and analyzed every 2 days to observe the effect of each treatment on the samples (Riaie et al., 2017; Vanoli et al., 2015). According to some previous research, putting an edible coating made of chitosan, salicylic acid, and thyme oil can extend the shelf life of fresh-cut melons by up to 11 days. Furthermore, many studies have highlighted the essential of storage in a controlled environment at ambient temperature (Carvalho et al., 2016; Ortiz-Duarte et al., 2019; Riaie et al., 2017; Sarengaowa et al., 2019).

Table 1. Composition of edible coating with combination of *Aloe vera* gel and CMC

Sample name	Sample code	Variables	
		***Aloe vera* (v/w)**	**CMC (v/w)**
Control	A0B0	0%	0
Sample 1	A1B0	30%	0
Sample 2	A1B1	30%	1%
Sample 3	A1B2	30%	3%
Sample 4	A2B0	50%	0
Sample 5	A2B1	50%	1%
Sample 6	A2B2	50%	3%

d. *Weight loss analysis*

All samples were weighed down on the first day of preparation and every 2 days interval for 10 days storage period. The weight loss can be calculated using Eq. 1 (Rasouli et al., 2019).

$$\%\ weight\ loss = \frac{sample\ weight\ in\ day\ 0,2,4,6,8\ and\ 10\ (g) - initial\ weight (g)}{initial\ weight\ (g)} x100\% \text{..........}(1)$$

e. *Titratable acidity analysis*

The analysis of titratable acidity followed the guidelines from AOAC (1995). A 10 g of each sample is combined, diluted, and filtered with filtration paper after being mixed with 250 mL of distilled water. 25 cc of the filtrate was then collected and titrated with a 0.1 N NaOH solution using phenolphthalein as the indicator. The Eq. 2 was used to determine the titratable acidity.

$$\%\ TA = \frac{volume\ NaOH\ (ml)\ x\ N\ NaOH\ x\ Dilution\ Factor\ x\ 100}{10\ gram\ of\ fresh\ sample} \text{.....}(2)$$

f. *Ascorbic acid value analysis*

Ascorbic acid contents were analysed based on iodometric titration methods. It is done by titrating 25 mL of mashed and diluted (10 g) sample with 0.01 N of iodine solution and starch as its indicator. The ascorbic acid contents were calculated using Eq. 3 (Dioha et al., 2012).

$$Vitamin\ C\ \left(\frac{mg}{100g}\right) = \frac{Volume\ Iodine\ (mL) x\ 0.88\ x\ Dilution\ Factor\ x\ 100}{10\ g\ of\ fresh\ sample} \text{.....................}(3)$$

g. *Color analysis*

The change in the color spectrum in each sample before and after coating for 10 days storage period was observed using a Colorimeter WR-10Q. The color change in the samples is based on $L*$, $a*$, and $b*$ values. The colorimeter was calibrated before the operation was carried out. It was then used to assess the color change in each sample by radiating a specific wavelength of light through the surface of each sample. The concentration of colored samples and their absorbance would be determined by the emitted light (Kortei et al., 2015; Perez-Gago et al., 2006).

h. *Soluble solids content analysis*

Sugar content was analysed using a Brix Refractometer to measure the sugar level in each sample before and after applying an edible coating for 10 days storage period (Rasouli et al., 2019).

i. *Microbial contamination analysis*

Microbial contamination was analysed through total plate count based on SNI 01-2332.3-2006, Indonesian National Standardization Agency or BSN (2006). This method is to count aerobic mesophyll bacteria contamination of each sample for 10 days storage period using PCA agar as its media.

j. *Firmness analysis*

Each sample's hardness was analysed using a GY-3 Sclerometer to evaluate the change in firmness of samples for 10 days storage period, which was stated in kg/mm (Li et al., 2020).

k. *Sensory analysis*

By the end of the storage period (day 10), the quality of all samples was assessed using sensory analysis. This was done using the sensory analysis methods based on SNI 01-2346-2006, BSN (2006). The respondents consisted of 30 inexperienced panels (13 men and 17 women) aged 20 to 21 years old. These panels were asked to rate the fresh-cut melons' color, hardness, aroma, and flavor.

Results and Discussion

The effect on the weight loss

Figure 1 demonstrates that, when compared to all the coated fruits, the untreated sample (control) has the highest weight loss. At the end of the 10-day storage period, sample 6 had a weight loss of 2%, while the sample with the highest weight loss was 8.49%. It has been demonstrated that the edible coating does, in fact, alter the weight loss of the freshly cut melon. The results showed that sample 6 has the highest *Aloe vera* gel and CMC concentration. Additionally, maximum weight loss may occur because no barrier is applied to the surface of fresh-cut fruits. This can result in gaseous exchange and microbiological contamination on the uncoated sample (control). From samples 1 to 4, it is known that the weight loss of these samples is higher than sample 6, which has the highest concentration of *Aloe vera* gel and CMC. *Aloe vera* gel in edible coating acts as a semipermeable barrier to the fruit surface, which can delay respiration and thus maintain the quality of fresh-cut fruits, such as weight loss, moisture loss, and reduced firmness. The previous study also reported that applying 100% *Aloe vera* gel as an edible coating on strawberries could significantly reduce the weight loss and respiration rate (Maan et al., 2021).

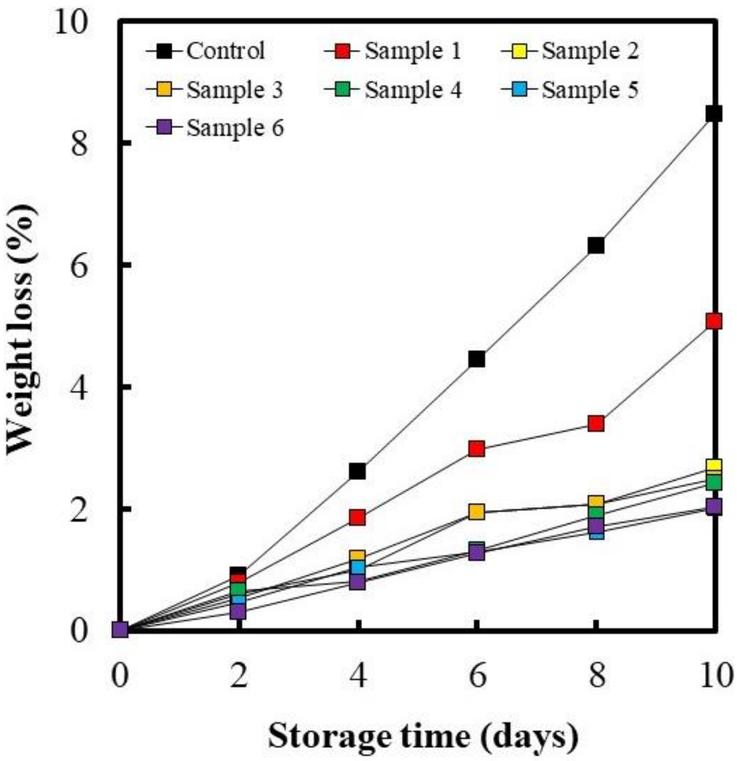

Figure 1. Effect of *Aloe vera*-based edible coating on the weight loss of fresh-cut melons. Control (uncoated sample); Sample 1 (30% AVG and 0% CMC); Sample 2 (30% AVG and 1% CMC); Sample 3 (30% AVG and 3% CMC); Sample 4 (50% AVG and 0% CMC); Sample 5 (50% AVG and 1% CMC); and Sample 6 (50% AVG and 3% CMC).

Furthermore, the application of CMC in this composition also has a significant effect. CMC can enhance the effectiveness of *Aloe vera* gel by improving its stability in *Aloe vera* gel molecules. Additionally, as an additive in *Aloe vera*-based edible coating, CMC is proven to maintain the firmness of fresh-cut fruits and reduce weight loss on fresh-cut fruits. It has several active substances such as calcium ions, which can bind the structure of membrane cells in fresh-cut fruits, thus leading to functional stability and strengthening the cell wall of the fruits (Panahirad et al., 2021).

The effect on the titratable acidity

Figure 2 shows that at day 0, all fresh-cut melons have titratable acidity level of 10 mg/100 g. The titratable acidity of most samples then declined on day 2 before dramatically increased until the end of the storage period (day 10). However, different results were shown by uncoated sample and sample 6 compared to other samples. The uncoated sample had the lowest titratable acidity until it began to increase on day 8 and had the highest titratable acidity at day 10, reaching 18 mg/100 g fresh sample. However, sample 6 has the highest titratable acidity until it began to decrease significantly on day 8. This sample also had the lowest titratable acidity at the end of storage time with the value of 9 mg/ 100 g fresh sample. This result is in line with a previous study by Mendy et al. (2019). Their study found that the titratable acidity of papaya increased during storage but significantly decreased when reaching at the ripening stages, possibly due to the reduction of organic acids triggered by the high respiratory process. Similarly, Falah (2014) also reported that the increasing acidity in melons represents maturity, indicating that fresh-cut fruits undergo the senescence phase and deterioration of fruit quality. This previous study also aligns with the findings shown in Figure 2. The uncoated sample has the highest titratable acidity at the end of storage time, while other samples (i.e., sample 2, 3, 4, and 5) show otherwise.

The effect on the ascorbic acid contents

Figure 3 shows on day 2 of storage, samples 1, 4, 5, and 6 experienced a slight increase in the ascorbic acid contents. After that, the ascorbic acid contents in all samples were continuously decreased until the end of storage time (day 10), with the highest value of 17.6 mg/100 g sample (from sample 6) and the lowest value of 8.8 mg/100 g sample (from control sample).

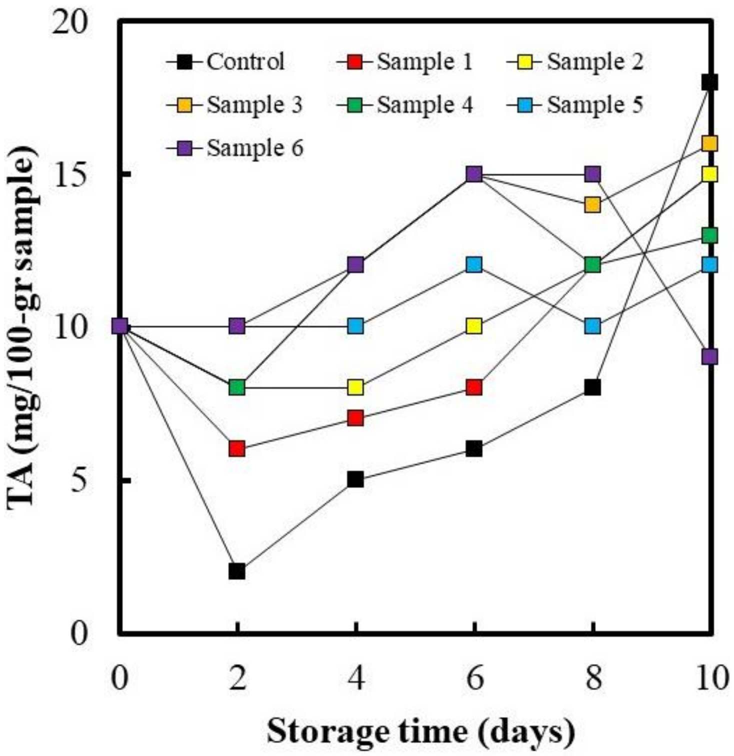

Figure 2. Effect of *Aloe vera*-based edible coating on the titratable acidity of fresh-cut melons. Control (uncoated sample); Sample 1 (30% AVG and 0% CMC); Sample 2 (30% AVG and 1% CMC); Sample 3 (30% AVG and 3% CMC); Sample 4 (50% AVG and 0% CMC); Sample 5 (50% AVG and 1% CMC); and Sample 6 (50% AVG and 3% CMC).

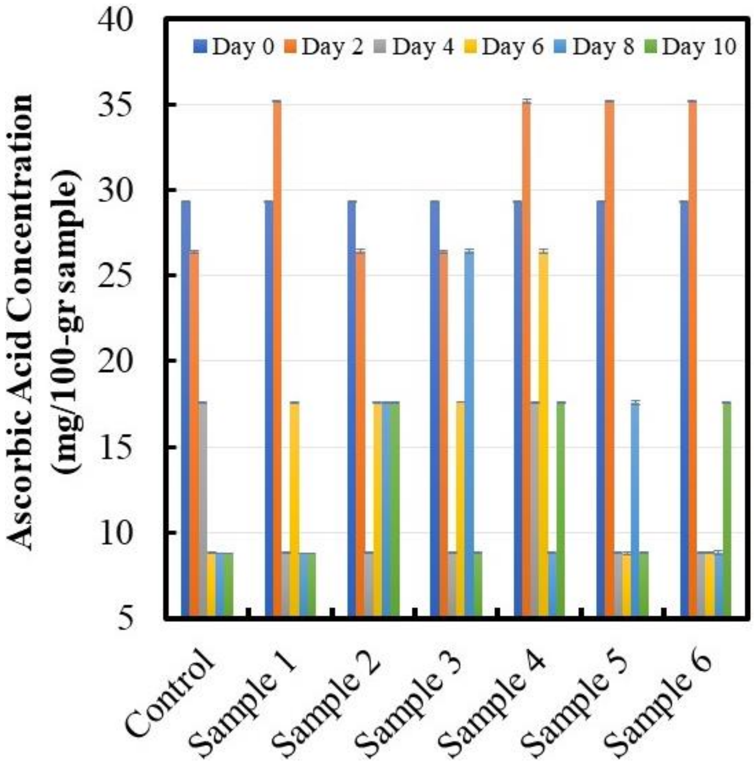

Figure 3. Effect of *Aloe vera*-based edible coating on the ascorbic acid contents of fresh-cut melons. Control (uncoated sample); Sample 1 (30% AVG and 0% CMC); Sample 2 (30% AVG and 1% CMC); Sample 3 (30% AVG and 3% CMC); Sample 4 (50% AVG and 0% CMC); Sample 5 (50% AVG and 1% CMC); and Sample 6 (50% AVG and 3% CMC). Vertical bars represent the standard error SE (n = 3).

The uncoated sample has the lowest ascorbic acid content since it has no barrier on the fruit surface that protects the fresh-cut melons from oxygen and ions contact with the fruits. The gaseous and ion contacts from the environment to the fruit surface during the storage period can trigger ascorbic acid's oxidative and enzymatic degradation, leading to decreased ascorbic acid contents in fresh-cut melons. It is also reported that a decrease in ascorbic acid contents can be due to ascorbic acid degradation, Maillard reaction, and anthraquinone oxidation (Rozana and Sunardi, 2021). On the other side, sample 6 (50% *Aloe vera* gel and 3% CMC) has the highest level of ascorbic acid contents because applying *Aloe vera*-based edible coating could provide a barrier between the fruit surface. Thus, it reduces the unwanted contact that can trigger the oxidative degradation of ascorbic acid contents. In addition, using *Aloe vera* as a base in the edible coating can maintain the content of ascorbic acids in fresh-cut melons. It is likely due to the bioactive compound *Aloe vera* (i.e., aloe-emodin). Aloe-emodin is reported to be able to prevent linolenic acid and anthraquinone degradation by up to 78%, thus preventing ascorbic acid degradation and protecting against lipid peroxidation (Nicolau-Lapeña et al., 2021).

The effect on the soluble solid contents

The soluble solid contents measured in this study also indicate the sugar content in each fresh-cut melon stored at room temperature for 10 days storage period. Figure 4 shows that all samples have the same sugar content level, proving that there is no significant difference between the uncoated and coated samples. The highest soluble solid contents found in all samples were on day 0 with a value of 6% of Brix, and the lowest was found at day 10 with a value of 2% of Brix. These results demonstrated that the respiration rate still occurred, thus leading to the degradation of organic sugars and the decline of fresh-cut melons quality. It also can affect the sensory quality of fresh-cut fruits, such as the flavor and aroma.

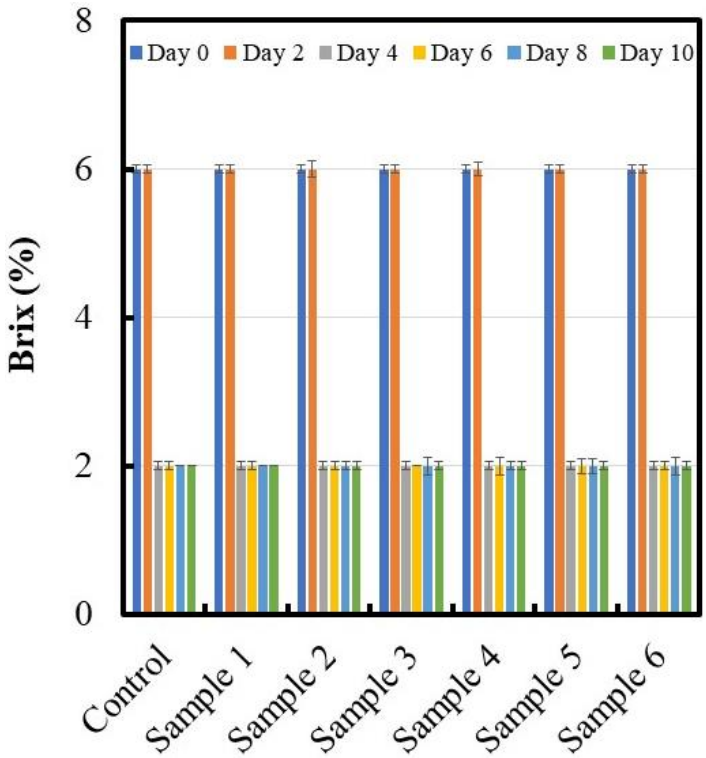

Figure 4. Effect of *Aloe vera*-based edible coating on the soluble solid contents of fresh-cut melons. Control (uncoated sample); Sample 1 (30% AVG and 0% CMC); Sample 2 (30% AVG and 1% CMC); Sample 3 (30% AVG and 3% CMC); Sample 4 (50% AVG and 0% CMC); Sample 5 (50% AVG and 1% CMC); and Sample 6 (50% AVG and 3% CMC). Vertical bars represent the standard error SE (n = 3).

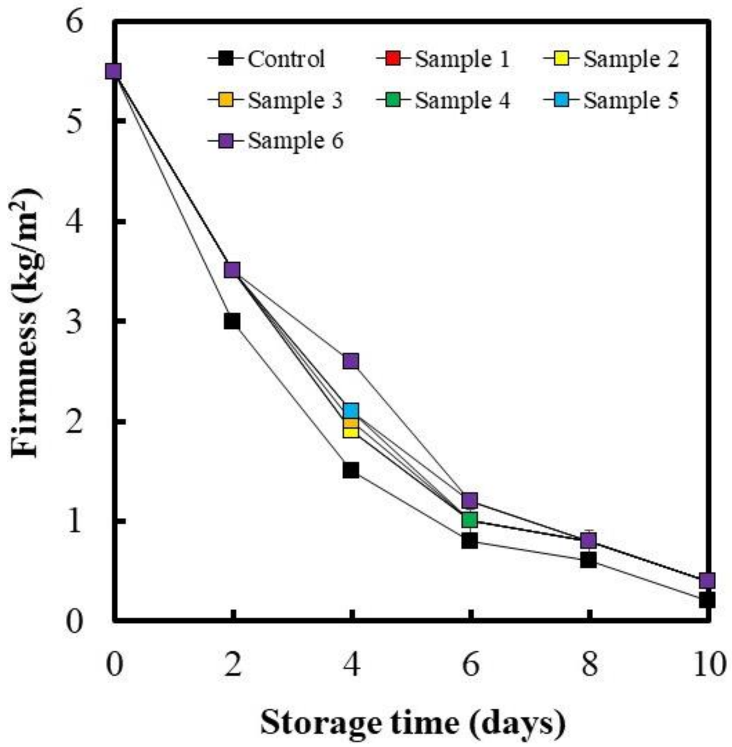

Figure 5. Effect of *Aloe vera*-based edible coating on the soluble solid contents of fresh-cut melons. Control (uncoated sample); Sample 1 (30% AVG and 0% CMC); Sample 2 (30% AVG and 1% CMC); Sample 3 (30% AVG and 3% CMC); Sample 4 (50% AVG and 0% CMC); Sample 5 (50% AVG and 1% CMC); and Sample 6 (50% AVG and 3% CMC).

The effect on the firmness

Figure 5 shows that the firmness of all fresh-cut melon samples started at 5.5 kg/cm^2 before gradually declining until day 10, with the values of 0.4 kg/cm^2 (coated samples) and 0.2 kg/cm^2 (uncoated sample). The results indicate that *Aloe vera*-based edible coating improved the firmness of fresh-cut melons as it protects on the fruit's membrane cells of and acts as a barrier from bacterial and yeast contamination that can affect the fruit's cell structure and hardness. These findings also align with a previous study by Maringgal et al. (2020), which stated that *Aloe vera*-based edible coating an improve and maintain the firmness of fruits by delaying the transpiration process from the inside of the fruits. Thus, not only maintaining the firmness but also reducing the weight loss on coated fruits better than uncoated fruit. However, the effect of *Aloe vera* gel concentration in this research has remained unknown whether the higher concentration of *Aloe vera* gel on edible coating provides the preferable firmness of fresh-cut melons compared to the lower concentration of *Aloe vera* gel.

The effect on the color

The results prove that *Aloe vera*-based edible coating improves the color quality of fresh-cut melons. The highest color change happened in uncoated samples because no barrier was applied to the fresh-cut melon surface to protect it from any gaseous or microbial contacts. Such contact can trigger an increase in the respiration rate and lead to the degradation of color in fruits. An improved value of color change found in sample 6 also proved that the composition of *Aloe vera* gel and CMC impacts on the edible coating (Figure 6). Coated samples with a higher *Aloe vera* gel and CMC concentration have a lower color change throughout the storage period than those with a lower concentration.

This study is supported by a previous study that reported that applying an edible coating can maintain color change in fresh-cut fruits. This is because the production of free radicals in fresh-cut fruits can be prevented, thus maintaining the fruit's membrane cells stability and delaying the color degradation or slowing down the browning effect (Maringgal et al., 2020). Moreover, the barrier provided by applying edible coating can prevent contact with oxidative substances from the environment. Thus, the degradation of bioactive substance that provides color in fruits (i.e., chlorophyll, anthocyanin, and carotenoid) can be avoided and the color change can be reduced (Nicolau-Lapeña et al., 2021).

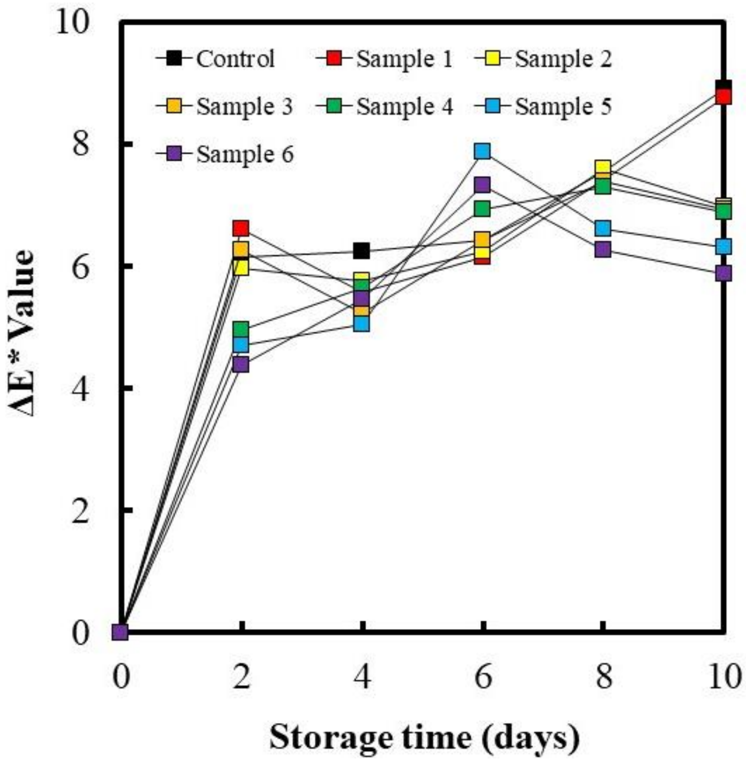

Figure 6. Effect of *Aloe vera*-based edible coating on the colour of Fresh-cut melons. Control (uncoated sample); Sample 1 (30% AVG and 0% CMC); Sample 2 (30% AVG and 1% CMC); Sample 3 (30% AVG and 3% CMC); Sample 4 (50% AVG and 0% CMC); Sample 5 (50% AVG and 1% CMC); and Sample 6 (50% AVG and 3% CMC).

The effect on the microbial contamination

In contrast, all coated samples have low microbial contamination, and sample 6 had the lowest microbial contamination with a value of $22x10^5$ CFU/mL bacteria (Figure 7). The uncoated sample has higher microbial contamination because there is no barrier between the fruit and the environment, thus resulting in oxygen contact with the fresh-cut melons. This condition provides aerobic mesophyll bacteria to grow or other microbial contacts from the environment. In addition, a previous study by Nasution et al. (2015) reported the effectiveness of *Aloe vera*-based edible coating in reducing the microbial contamination of fresh-cut guava. They reported that applying 100% *Aloe vera* gel edible coating on fresh-cut guava significantly reduces microbial contamination. This is because *Aloe vera* gel has beneficial bioactive substances (i.e., pyro catechol, cinnamic acid, and p-coumaric acid) which can enhance the defence of fruit cell tissue against bacterial attack in such a way that the cell walls become stronger compared to the uncoated sample.

The effect on the sensory analysis

Figure 8 shows that the uncoated samples have the lowest distribution of sensory scores, with an average score of 1.2 (color), 1.0 (aroma), 1.0 (texture), and 1.0 (taste), respectively. Again, sample 6 provides an improved quality with a higher distribution of each score compared to all samples, with an average score of 2.3 (color), 1.7 (aroma), 1.9 (texture), and 1.6 (taste). Overall, most of the panellists gave a score of 1 to all sensory aspects, indicating that the sample has a very dull yellowish color, a spoiled smell, a very soft texture (i.e., easily breaks), and a slightly rotten sour taste. This showed that the senescence process occurred in the fruit might have started on day 4 of storage. Furthermore, the results also indicates that the low quality that occurred in control can be caused by the absence of protection of the edible coating which also proven in all the coated samples. *Aloe vera* and CMC in this scenario prove the significance effect and difference of all the coated sample by total score given by all panellists by the end of the storage period. In addition, the highest concentration of *Aloe vera* and CMC is more efficient and effective in maintaining the quality of fresh-cut melons and also can be a better alternative solution to maintain the quality of fresh-cut melons.

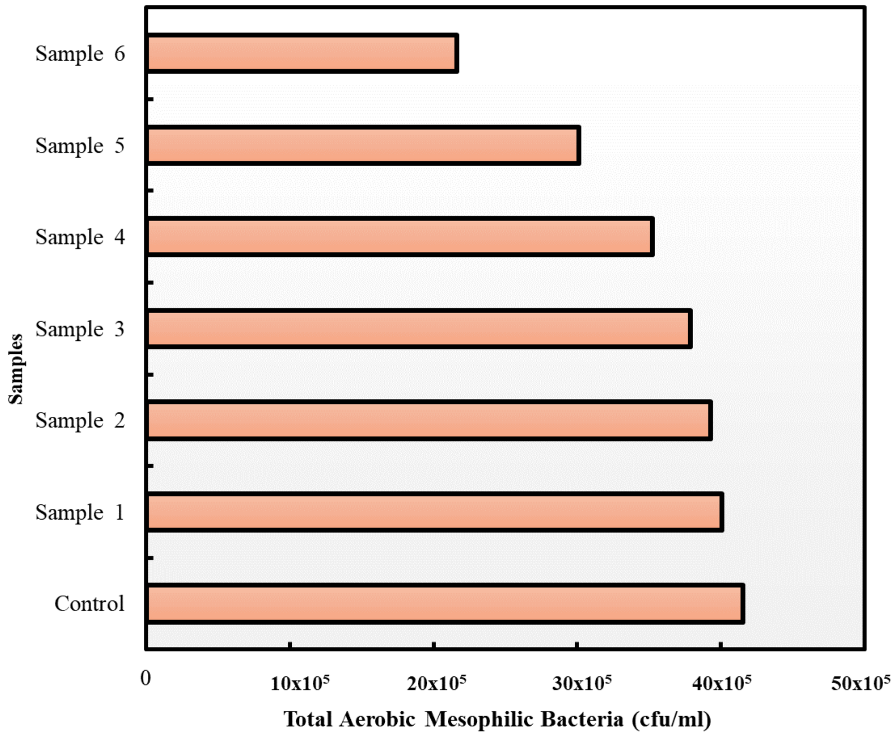

Figure 7. Effect of *Aloe vera*-based edible coating on the microbial contamination of fresh-cut melons. Control (uncoated sample); Sample 1 (30% AVG and 0% CMC); Sample 2 (30% AVG and 1% CMC); Sample 3 (30% AVG and 3% CMC); Sample 4 (50% AVG and 0% CMC); Sample 5 (50% AVG and 1% CMC); and Sample 6 (50% AVG and 3% CMC).

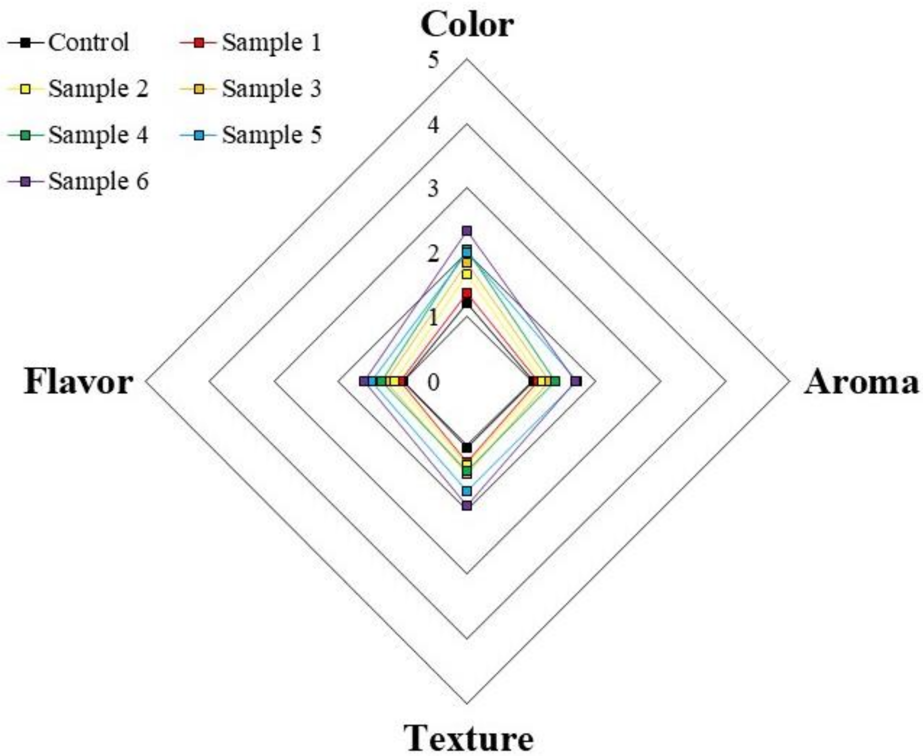

Figure 8. Effect of *Aloe vera*-based edible coating on the sensory analysis of Fresh-cut Melons. Control (uncoated sample); Sample 1 (30% AVG and 0% CMC); Sample 2 (30% AVG and 1% CMC); Sample 3 (30% AVG and 3% CMC); Sample 4 (50% AVG and 0% CMC); Sample 5 (50% AVG and 1% CMC); and Sample 6 (50% AVG and 3% CMC).

Conclusion

This study demonstrated that adding *Aloe vera* gel and CMC at different concentrations improved fresh-cut melons' quality and sensory aspects of to a different extent. The best quality of fresh-cut melons stored at room temperature (30ºC) for 10 days was sample 6 coated with the highest concentration of *Aloe vera* gel (50%) and CMC (3%). However, the uncoated fresh-cut sample showed contradictory results. Therefore, Aloe *vera* gel is potential as an ingredient for edible coating for fresh-cut fruits. Further in-depth study, however, is required to investigate the optimum concentration of *Aloe vera* gel for an effective application.

Declarations

Conflict of interests The authors declare no competing interests.

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