Edible coating development to extend shelf life of mangoes
\textit{(Mangivera indica \textit{L}.)}

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Abstract. Mango is one of the most favored tropical fruits which potentially as an export commodity in Indonesia. However, this fruit is easily damaged and has a short shelf life. One way to extend the shelf life of fruits is to use edible coatings. This study aimed to determine the effect of storage temperature and edible coatings on the shelf life of mangoes. Using 6.4% beeswax and a composite of 10% Arabic gum and 1% chitosan as edible coatings, these results were compared to control. Several parameters were used to evaluate the effectiveness of edible coatings, specifically weight loss, pH, fruit skin color, fruit flesh color, hardness, decay incidence (DI), and soluble solids concentration (SSC). Mangoes were stored in a variety of storage conditions, namely room temperature (26.5\textdegree C), showcase (10.2\textdegree C), and wine cooler (12.4\textdegree C). Experimental results indicated that applicating edible coatings and storing fruits at lower temperatures generally could reduce weight loss above 20% and DI by 85%, slowing changes in SSC, pH, and color of the fruits’ skin and flesh, as well as maintaining hardness. Moreover, 6.4% beeswax was more effective than the composite of 10% Arabic gum and 1% chitosan in extending the shelf life of mangoes.

1. Introductions
Fruits are rich in carbohydrates, vitamins, and minerals, as well as low protein content with a pH value ranging from 7 to slightly acidic and high water content. They are easily damaged because they contain 80-90\% water of their total weight [1]. These conditions are suitable for the growth of bacteria, fungi, and molds [7, 10].

Indonesia has very diverse types of tropical fruits which have the potential to become an export commodity. The main of Indonesia’s annual fruits are bananas, mangoes, oranges/tangerines, pineapples, and durians which almost of all are produced in every province in Indonesia. Since the climacteric fruit ripening process will continue after being picked from the tree, mangoes should be harvested when they reach maximum growth but are not yet ripe [11]. For mangoes that will be transported out of town or for export, the ripeness of the mango harvested is usually 60-70\%, thus the mangoes are not damaged during the transportation and are 90-100\% ripe until their destination.

Using edible coatings to coat the fruits is one of the methods developed to extend the shelf life of fruits. A thin layer is formed by the edible coating that is safe for consumption as well as protects the fruits from oxygen, moisture, and microbes. Edible coatings have a high potential to control browning activity, foul-smelling activity, unpleasant taste, and microbial activity of fruits and vegetables [9]. The main benefit of using edible coatings is that some of the active ingredients can be incorporated into the polymer matrix and consumed with food, thereby increasing safety or even nutritional and sensory attributes [1].
Coated mangoes using Arabic gum 10% and chitosan 1% could reduce mass loss, respiration rate, ethylene production, change in soluble solid concentration (SSC), decay incidence (DI), and maintain firmness. This proves that their application as natural preservative are a simple and effective technique to delay ripening and maintain mango fruit quality during cold storage (13°C; 80% RH for 28 days) without using fungicides [2]. In addition, several external factors also affect the fruit shelf life, such as temperature which will be investigated further in this study. Arumanis mango (Mangifera indica L. var. arum manis) is used then it is coated with Arabic gum and chitosan as composite and beeswax. The fruits are stored at room temperature (26.5°C), wine cooler (12.4°C), and showcase (10.2°C). This study aimed to determine the effect of storage temperature and edible coatings on the shelf life of mangoes.

2. Material and Methods
The fruits used in this research were Arumanis mangoes (Mangifera indica L. var. arum manis) with a maturity level of 70% which were characterized by a slight aroma, hard texture when pressed, and the absence of black spots on the mangoes. While the mangoes were obtained from Griya supermarket which is located in Jatinangor, West Java, Indonesia, the ingredients for making edible coatings bought from Cipta Kimia, Jakarta, Indonesia for Arabic gum, Monodon Group, Lampung, Indonesia for chitosan, and farmer in Berau Barat, Indonesia for beeswax.

The research method consisted of several stages, namely preparation and washing, coating the fruits with edible coatings, then fruits storage and testing. The edible coatings treatment on mangoes were (1) aqua dm as control, (2) Arabic gum 10% + chitosan 1% as composite, and (3) beeswax 6.4%. After the fruits had been coated, they were stored at several temperatures such as room temperature (26.5°C), 12.4°C using a wine cooler (Polytron SCN 233D), and 10.2°C using showcase (GEA XW-85).

The fruits were tested by measuring weight loss, hardness, skin and flesh color, decay incidence (DI), soluble solids concentration (SSC), and pH. To measure the weight loss, two mangoes from each group were marked separately before being stored and weighed using a scale (Ningbo ETDZ Hansen Measurement Co., Ltd) at the beginning of the experiment then these same fruits were weighed consistently every 7 days. The results were then calculated as a percentage by comparing the mass of the sample in a certain time range with the mass of the initial sample.

Fruit hardness was measured using a texture analyzer (Stable Micro Systems serial number 41141) with blade probe, while the color of the skin and flesh was measured by colorimeter (3NH Technology Co., Ltd type NH310). These measurements were carried out at several different locations such as the top, middle, and bottom of the fruits. The color measurement results from the colorimeter are then converted to the total color change (ΔE) by the following formula:

\[ \Delta E = (\Delta L^2 + \Delta a^*^2 + \Delta b^*^2)^{0.5} \]  

(1)

These results were compared with the results of measuring ΔE of the flesh and skin color on day 0 of the experiment. DI and SSC measurements were carried out using the method described by Khaliq et al (2016). Samples preparation for pH testing is the same as that used for SSC testing. The fruits’ pH was measured by using a pH meter (pH buffer groups USA model 220).

3. Results and Discussion
3.1. Effect of Storage Temperature on Mangoes
Figure 1 represents that the fruit weight loss increased along with the rise in storage temperature and time for each variation of edible coatings. Therefore, the smaller fruit weight loss indicated better results, as a consequence of reducing metabolic activity as well as slowing the chemical changes at the lower storage temperature. While the smallest weight loss from each type of coating variation was the mango that was stored in a showcase (10.2°C), the largest was found in those stored at room temperature.

The optimum temperature for storing mangoes is at 13°C with an RH of 85-95% which can provide a shelf life of 2-3 weeks for mature green mangoes [6], almost similar to the wine cooler’s temperature (12.4°C), thus storage mangoes in a wine cooler should be able to minimize the weight loss. However, this research results showed that storing mangoes at a showcase (10.2°C) retained their moisture better than in wine cooler (12.4°C) because the storage relative humidity level was too low (RH 65% and 71%)
compared to the optimum (RH 85-95%) as well as unstable storage conditions in the wine cooler due to too many mangoes stored in the wine cooler resulted with the slow and uneven of the cooling process.

Based on figure 2, decay incidence (DI) as an indicator of the level of fruit rot continued to rise along the period. The lower value of DI implied that the fruit underwent a slower decay process. On the 17th day of storage, for control and beeswax coating treatments, a lower storage temperature could reduce the DI. The largest DI occurred on the control stored at room temperature compared to mango coated with beeswax stored in the wine cooler (12.4°C) which was the least.

3.2. Effect of Edible Coatings on Mangoes

3.2.1. Weight loss

Weight loss was used as an index of fruit quality during storage whose value would continue to rise over the time. The control had the largest weight loss at the end of the period, which were 25.9%, 25.74%, and 17.75% for mangoes that used storage temperature at room temperature, showcase, and wine cooler, respectively. On the contrary, the smallest weight loss was found in mangoes that used beeswax as edible coatings, which was only 5.19% for showcase storage and 8.72% for room temperature storage. In addition, the lowest weight loss of mangoes for storage at wine cooler with a value of just under 20% was experienced by mangoes coated with Arabic gum and chitosan.

Based on figure 3, beeswax had a better impact in reducing fruit weight loss compared to Arabic gum and chitosan. Due to Arabic gum and chitosan are carbohydrate-based edible coatings that have strong hydrophilic properties, they produce water vapor and do not work well at blocking gas formation.
Meanwhile, beeswax is a lipid-based edible coating that has hydrophobic properties thus it is better at preventing moisture loss. The weight loss of fruits coated with edible coatings was lower than the control because of they form a barrier to mass transfer such as water, oxygen, and solutes, as well as slow down transpiration (the difference of water pressure at the outside and inside the fruit) and respiration.

3.2.2. Decay Incidence (DI)
Decay incidence (DI) of mangoes from each treatment rose over time which the highest was occurred in control stored at room temperature, as shown in figure 4. However, mangoes coated with Arabic gum and chitosan had a higher DI value than two other variations at showcase storage and it had almost the same value as the control in wine cooler storage. Whereas, Arabic gum and chitosan should reduce the DI value because of their film-foaming properties that can inhibit the microbial process in the fruit [2]. As mentioned in Chapter 3.1, this can occur due to the low relative humidity of storage compared to its optimum storage at 85-90% also the storage conditions in the wine cooler are less stable, and too many mangoes were stored resulting in the slow and uneven of the cooling process.

The DI value of mangoes coated with beeswax was the lowest compared to the others for each temperature storage. This is supported by the result of the mangoes weight loss testing, which was also the smallest than others due to the hydrophilic nature of beeswax. Using edible coating should be able to inhibit the respiration and transpiration process then reduce changes in physiochemical properties.

![Figure 4](image.png)

**Figure 4.** Changes in the DI of mangoes on storage at (a) room temperature 26.5°C, (b) showcase 10.2°C, and (c) wine cooler 12.4°C over storage time.

3.2.3. Soluble Solids Concentration (SSC)

![Figure 5](image.png)

**Figure 5.** SSC changes of mangoes on storage in the wine cooler 12.4°C over time.

SSC is an index of fruit maturity and is often used to measure fruit quality since the ratio of sugar to acid has a significant role in determining the level of ripeness and taste of the fruit. SSC increased gradually until the mango fruit was ripe due to the increase in carbohydrates into simple sugars and
During the ripening process, starch is hydrolyzed into simple sugars, such as glucose, fructose, and sucrose which are predominant in ripe fruit. The increasing amount of enzymes sucrose synthase, invertase, and amylase hydrolyzed starch to sucrose [2].

The SSC of mango beeswax variation on storage in the wine cooler at 12.4°C tends to be the lowest among others, as shown in figure 5. The fruit coated with edible coating had a lower SSC value than the control because edible coatings provide an excellent semipermeable barrier around the fruit that can modify the fruit's internal atmosphere by reducing oxygen, increasing carbon dioxide, and suppressing ethylene production. The decrease in respiration rate will slow down synthesis and utilization of metabolites, as well as conversion of starch to sugar, thereby reducing the SSC value [5].

3.2.4. pH

The pH test is carried out to measure the strength of the acid contained in the fruit. Its value of the fruit would continue to increase until a certain day, then decreased over the storage period, caused by a decrease and increase in the level of acid content in the fruit.

As is presented in figure 6, mangoes in each variation experienced an increase in pH up to a certain day, then the pH turned to decrease. For control, pH experienced an upward tendency over a-29-days of periods, then it declined until the end of the period. Meanwhile, both mangoes coated with Arabic gum and chitosan and beeswax experienced an upward trend and reached a peak at the 15th day, then it decreased. The increasing acidity of stored fruits occurs due to the formation of carbonic acid or the production of acid from the fermentation of sugar. Moreover, the decrease in acidity occurs when the fruit is ripe because the levels of malic acid and citric acid are reduced supports the formation of sugar.

Figure 6 reveals that the lowest change in pH occurred in the beeswax variety mango. The use of beeswax in mangoes can reduce the respiration rate of the fruit so that the utilization of organic acids can be delayed. In addition, the change in pH of the control variation mango had the highest value. This is because the edible coating layer acts as a semipermeable layer that functions in delaying fruit ripening by slowing the respiration rate of the fruit so that it affects the formation of acid [5].

3.2.5. Skin color

Based on figure 7, the ΔE value of mango skin tended to increase. On the last day of fruit storage, the ΔE value of mango peel was in the range 11 - 49, which indicated that the skin color was more likely to be different. The color changed from green to yellowish-green in mango was caused by the degradation of chlorophyll and the appearance of carotenoid yellow pigments. Carotenoids are stable compounds synthesized during the developmental stage but are masked by the presence of chlorophyll.

After 15 days, the mangoes began to show blackish spots which were getting bigger due to the high natural sugar content in the fruit and indicating the maximum maturity level of the mangoes. The mangoes which were threatened by edible coatings had a smaller chance of ΔE compared to the control. This depicts that edible coating provided a protective layer for the fruit, thereby reducing the rate of damage that caused changes in the skin color of the fruit due to metabolic processes and microorganism activity. Treating mango fruit using edible coating could also slow down the respiration rate of the fruit and inhibit the rate of ethylene production to create a modified atmosphere around the fruits. In addition, the delay of mangoes skins’ color can be caused by the decreased rate of chlorophyll degradation in the mango skin tissues [8].

3.2.6. Flesh color

Based on Figure 8, the value of ΔE of mango flesh tends to increase over storage time. On the end of the storage period, the ΔE value of mango flesh was in the range 11 - 49, which signified that the flesh color was more likely to be different, because of the yellow color of the mango flesh changes to an orange color enzymatically. At the end of the storage period, mangoes showed a reduction in the total amount of carotenoids which could be associated with the oxidation reaction of pigments or phenolic
compounds causing darkening of the mango flesh [4]. Treated mango fruit with beeswax experienced the smallest change in the value of ΔE of the flesh compared to others. Therefore, the edible coating provided a protective layer for the mangoes, thereby reducing the rate of damage that led discoloration of the fruit flesh due to metabolic processes and microorganism activity.

Figure 7. The ΔE of mangoes skin on storage in the wine cooler 12.4°C over storage time.

Figure 8. The ΔE of mangoes flesh on storage in the wine cooler 12.4°C over storage time.

3.2.7. Texture (Hardness)
The level of fruit maturity can be determined by reducing the level of fruit hardness because its flesh will be more tender and juicy during the fruit ripening process. According to figure 9, the hardness value of beeswax variation is the greatest among others. However, mangoes coated with edible coating had a firmer fruit texture than control. As a result of a modified atmosphere that was formed by the edible coatings around the surface of the fruit, thus affected the delay in changing the texture of the fruit [2]. In addition, the edible coating was able to prevent water loss and maintain fruit hardness, as the fruit softening is influenced by the loss of water content in the fruit and associated with enzymatic hydrolysis reactions of cell wall components and pectin degradation. Moreover, the use of edible coatings inhibited the respiration process as the breakdown of carbohydrates into water-soluble compounds was reduced.

Figure 9. The changes of hardness on storage in the wine cooler 12.4°C over storage time.

4. Conclusions
Based on this research, it could be concluded that stored mangoes at lower temperatures and coated with edible coatings in general, could reduce weight loss and decay incidence (DI), slow down soluble solids concentration (SSC) changes, pH, and color on the skin and flesh of the fruit, and maintain fruit hardness. However, the application of beeswax was more recommended than Arabic gum and chitosan.

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