Physiological activity of banana coated with sago starch and cellulose nanofiber edible coating

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Abstract. Combination of sago starch with cellulose nanofiber (CNF) was developed to produce edible films and coatings for agriculture product. This research aimed to evaluate the effect of CNF concentration on sago starch edible coating for controlling the postharvest physiological activity to delay the deterioration of banana at room temperature. Effectiveness of sago starch edible coating with varying concentration of CNF (1%, 3%, 5%, 7%, and 9%) was examined against water vapor permeability (WVP) of film and the changes in fruit physiochemical parameters including color change, total soluble solid, weight loss, and respiration. The results showed that edible coating based on sago starch blended with CNF effectively delayed the fruit color change and decreased the soluble solid content. In conclusion, sago starch with 9% CNF coatings was effective for extending the shelf life of the banana fruit at room temperature.

1. Introduction

Banana (Musaceae) is one of the most popular tropical fruits with a high nutrition, good taste and availability. Banana is used as source of energy, vitamins and bioactive compounds which are beneficial for health. It contains high antioxidant due to the presence of vitamin A, C, E, and β carotene [1-3]. However, as a climacteric fruit, banana undergo increase of respiration after harvest which affects its shelf-life and physiological changes during transportation and storage. Therefore, a preservation technique is required to control the sensory quality and nutrition loss after harvest or during marketing time.

Currently, coating is considered as an innovative, effective, and safe method to extend the shelf-life of the fruit and fresh vegetables. Coating application on fruit and vegetable surfaces can extend the shelf-life by reducing the water loss by developing semipermeable network of the cohesive molecules that covers the surface [4], inhibiting the ethylene production [5], maintaining the volatile component within the fruit [2], and slowing down the respiration rate [6].

The most potential polymer used in edible coating and has been widely discovered is the starch-based polymer. Starch, such as sago, is one of the naturally abundant polysaccharides which easily decomposed and easily obtained with a relatively low prize. In general, starch coatings show a good gas barrier characteristic and well-attached on the surface of the fruit and vegetables. However, due to their hydrophilic nature, they have low water-resistance which influences its stability and mechanic characteristic. The low stability of the coating film will shorten the storage time; thus, it becomes less
effective as the moisture and microbes that permeated the film will rotten the foodstuffs. Mechanical and barrier properties against water vapor of the biopolymer film can be increased by adding the nano reinforcement like nano cellulose [1,7].

Nanocellulose is a nano-sized cellulose (diameter of <100 nm) which has unique characteristics, such as very strong, large surface volume ration, high water-binding capacity, high tensile strength, smooth tissue, and highly porous. Application of nanocellulose as filler in biopolymer matrix can increase the barrier characteristics toward gas and moisture, and increase the mechanical characteristics of the composite film to be applied in food packaging or as coating like in alginate [7] and pectin [8], chitosan [1], potato starch, tapioca starch and chitosan [9], and mango starch [10]. To date, development of edible coating with sago starch combined with cellulose nano fiber is yet to be explored. Thus, this study aimed at find out the influence of nanocellulose concentration on the characteristics of edible coating and physiology quality of the banana during storage period.

2. Materials and methods

2.1. Materials
The study used Mas Kirana banana which was obtained from Giwangan fruit market in Yogyakarta. The cellulose nanofiber (CNF) gel of 4% concentrate was produced by Nano Novin Polymer Co, Iran. The sago starch produced by Small and Medium Enterprise.

2.2. Preparation of coating formulation
Amounting of 25 grams of sago starch was dissolved in 500 ml aquadest (1:20) and was stirred using magnetic stirrer (500 rpm) in a room temperature for 10 minutes. At the same time, cellulose nano fiber (CNF) was stirred using magnetic stirrer for 15 minutes in room temperature. Then, the CNF was divided into different concentrations, namely 1% (treatment A), 3% (treatment B), 5% (treatment C), 7% (treatment D), and 9% (treatment E). These different concentrations were based on the percentage of CNF toward the weight of the sago starch. These different concentrations were then added into the sago starch solution. The CNF solution and sago starch solution were heated at the temperature of 65°C and stirred using magnetic stirrer (500 rpm). Upon reaching the 65°C, 0.02% (w/v) Tween 80 was added into the starch solution and CNF. The mixture was heated at 70°C and stirred using hotplate stirrer. Following the gelatinization of the sago starch in 70°C, 0.6% (w/v) of glycerol was added and stirred in the temperature of about 70°C for 15 minutes [1,10,11]. The influence of coating solution made from sago starch and SNF was then tested.

2.3. Coating application on banana fruit
Prior to the coating application, the bananas were washed with aquadest and air-dried. Then, the bananas were dipped for one minute into the edible coating made of sago starch with different CNF concentrations (1%, 3%, 5%, 7% dan 9%). The dipped bananas were then air-dried using fan for one hour until the surface became dry. The coated bananas and uncoated bananas were stored in room temperature to observe the change of quality in the fruit, the weight loss, color changes, respiration speed for one-week storage.

2.4. Color measurement
The color of the coated and uncoated bananas was measured by using color meter. The measurement was carried out by sticking the tool’s sensor on the surface of the tested fruit. There are three locations of the tested fruit, the tip, the middle, and the base of the fruit. The treatment was repeated each day for three tested samples during the storage time period.

2.5. Weight loss
The coated and control bananas were previously weighed before stored (W₀) and stored during a period of time in room temperature. During the storage time, the weight of the sample was measured
daily [4,12]. Three bananas for each type of samples were measured daily. Then the weight loss was calculated using the following formula:

\[ \% \text{ Weight loss} = \left( \frac{W_0 - W_t}{W_0} \right) \times 100 \]  

(1)

2.6. Total soluble solid (TSS)

The measurement of total soluble solid (TSS) was carried out by cutting the samples into small parts and squeezed. The total dissolved solids were measured using HANNA digital hand refractometer. This measurement was carried out in three parts of the fruit, namely the tip, the middle, and the base. The amount of TSS was stated in °Brix [13,14].

2.7. Respiration rate

Respiration rate was measured using the closed-system [15]. The banana samples were stored in air-tight jug sized 0.5 liter (each jar is filled with 2 fruits) as respirator with an insulation wall and sealed with gas sample. The glass jar was then stored in a room temperature and the gas sample was taken using probe needle through rubber-insulation wall. During one week room-temperature storage time, the O\(_2\) and CO\(_2\) contents were measured using the oxygen meter (Brand Lutron DO-5510) every six hours for seven days storage time. Fonseca et al. [15] noted that the respiration rate can be calculated using the following formulas:

\[ R_{O_2} = \frac{(Y_{t1}O_2 - Y_{t2}O_2) \times V_f}{100 \times w \times (t_2 - t_1)} \]  

(2)

\[ R_{CO_2} = \frac{(Y_{t1}CO_2 - Y_{t2}CO_2) \times V_f}{100 \times w \times (t_2 - t_1)} \]  

(3)

Where, \( R_{O_2} \) = the \( (O_2) \) consumption rate (mL kg\(^{-1}\) h\(^{-1}\)); \( R_{CO_2} \) = the carbon dioxide (CO\(_2\)) production rate (mL kg\(^{-1}\) h\(^{-1}\)); \( Y_{t1}O_2 \) and \( Y_{t2}O_2 \) = oxygen concentrations (%) at \( t_1 \) and \( t_2 \) times (hour); \( Y_{t1}CO_2 \) and \( Y_{t2}CO_2 \) = carbon dioxide concentrations (%) at \( t_2 \) and \( t_1 \) times (hour); \( w \) = the weight of the coated fruit; \( V_f \) = the free volume within the respirator jar.

2.8. Statistical analysis

One-way ANOVA was carried out to determine the significant of cellulose nanofiber concentration on color, weight loss, TSS and respiration rate using SPSSS software. The result was considered to be significantly different at \( P < 0.05 \).

3. Results and discussion

3.1. Color

Color is a parameter to predict the ripening and aging processes of the banana fruit, which indicated by changes of the fruit skin’s color from green to yellow to brown as the consequence of too long storage time [12].

Coated bananas showed a slower color change compared to uncoated banana (control; Figure 1). Addition of CNF on sago starch as edible coating on bananas influence the changes of color on L (lightness) parameter, and the value of ‘a’ (P<0.05). Whereas, the storage time influences the L value and the ‘b’ value of the bananas (P<0.05). Interaction between concentrates of CNF and length of storage time did not influence three color parameters.

The L value of uncoated banana on the second day indicated that the color of the bananas is getting lighter and have started to ripening. The L value is started to decrease since the bananas’ color starts to turn darker or brownish due to aging. Whereas, the coated bananas show the slower increase of L value. Similarly, the control fruit increase the ‘a’ value on the second day to positive value (1.61) which indicates the changes of bananas skin color from green to yellow. The ‘a’ value steadily increases into the sixth day with the value of 16.09. Meanwhile, the coated bananas for all treatments showed negative value up to the sixth day of storage (-0.32 - -18.35), which indicated that the ripening process was much slower. Similar result was also shown by Hue° of the uncoated bananas value which
decreased from 118.35° to 87.75° on the second day of storage, which means that the color has started to turn yellow on the second day. Coated bananas showed a slower color change since the coating solution provide protection toward the loss of moisture and slowdown respiration rate. The decrease of respiration rate caused the slower chlorophyl change, hence, slowdown the ripening of the banana [12].

3.2. Total soluble solid (TSS)

The TSS is the best indicator for the fruit ripening because the starch is hydrolyzed into glucose during the ripening process [1].
the seventh day of storage to 28.7%. Meanwhile, the coated bananas have smaller TSS on the third day of storage by 12.7–16.9 °Brix. After 7 days storage in a room temperature, the TSS content in sago starch and CNF-coated bananas was 18.3–25.9 °Brix. This low value of TSS indicated that the coating method using the coating formula with sago starch added with nano cellulose can prevent the ripening process [1,7].

TSS content is influenced by the CNF concentration (P<0.05), storage time (P<0.05) and interaction between CNF concentration and storage time (P<0.05). Edible coating in this study showed that the TSS content in banana tended to be lower parallel to the increased CNF on sago starch matrix. The lowest TSS was exhibited by the sago starch coating formulas added with 5% and 9% of CNF by 21.8% and 22.9%, respectively, on the seventh day of storage in room temperature. This showed that addition of CNF on sago starch matrix can slowdown the ripening process of banana fruit. This process was due to the reduction of respiration rate [7].

3.3. Weight loss
Following the harvest, fruit and vegetables are easily experience water loss which further reduce the quality of the products like weight loss and lower price [10].

The average weight loss per day for coated bananas was lower compared to the uncoated bananas (Figure 3). Coated banana showed the weight loss of 3.5–15.5% each day. Whereas, the weight loss of the uncoated bananas was 3.8–16.7%. Treatment E, with 9% addition of CNF on sago starch produced the lowest weight loss by only 15.5% compared to other treatments. The decrease of weight loss was due to the increased of barrier toward the moisture from coating solution of sago starch added with CNF. In addition, the fiber shape or CNF columnar could reduce the free space within the sago starch matrix, hence, prevent and slowdown the moisture movement within the banana fruit that may cause moisture loss [16]. This study also revealed that the CNF concentration on sago starch-based coating and interaction between the CNF concentration and the length of storage time influenced the weight loss of the banana stored within the room temperature (P<0.05). Wettability of the coating formula on epicarp layer of banana tended to increase with the increased of nanofiber cellulose’s, glycerol and gelatin concentrations [17].

3.4. Respiration
The ripening process within the climacteric fruit like banana is characterized by the increase of respiration rate together with metabolic changes.

Combination of sago starch and CNF-coated bananas showed higher level of oxygen concentration compared to the coated bananas without CNF and uncoated bananas at the end of the storage time (Figure 4a). The highest level of O2 was found on the coated bananas added with 1% and 9% CNF within the sago starch matrix by about 4% and the lowest oxygen concentrate was found on uncoated bananas (control) by 1%. Further, addition of 5 and 7% CNF within the sago starch matrix produced
the lowest \( \text{CO}_2 \) at the end of the storage time by 12%. This finding indicated that the coating treatment can serve as barrier toward the \( \text{O}_2 \) and \( \text{CO}_2 \), hence, can slowdown the respiration rate on bananas.

![Measurement result of \( \text{O}_2 \) and \( \text{CO}_2 \) concentrate of banana respiration during storage](image)

**Figure 4.** Measurement result of \( \text{O}_2 \) (a) and \( \text{CO}_2 \) (b) concentrate of banana respiration during storage

![Respiration rate of \( \text{O}_2 \) of control and coated banana](image)

**Figure 5.** Respiration rate of \( \text{O}_2 \) of the control and coated banana

![Respiration rate of \( \text{CO}_2 \) of control and coated banana](image)

**Figure 6.** Respiration rate of \( \text{CO}_2 \) of control and coated banana

CNF concentration on sago starch coating influenced the respiration rate toward the consumption of \( \text{O}_2 \) and \( \text{CO}_2 \) production (\( P<0.05 \)). Respiration rate of oxygen consumption (Figure 5) was similar up to the third day of storage (72 hours) and increased thereafter. Bananas coated with sago starch added with 5% and 9% CNF showed the slower climacteric peak compared to other treatments. This showed that highest respiration rate occurred in the 96th hours for bananas coated with sago starch and 5% CNF. Whereas, for other treatments, the highest respiration rate occurred in the 72nd to 84th hours of storage. Further, consumption rate of oxygen was stable up to the seventh day of storage. The
respiration rate of carbon dioxide production of coated bananas with 5% of CNF was slower compared to other treatments.

Figure 7 shows that the type of substrate oxidized during respiration up to the 72\textsuperscript{nd} storage hour was fat in all treatments, except on bananas coated with sago starch and 3\% of CNF. This was shown by RQ < 1 in all treatments except treatment B who has RQ value of 1.28 on the third day of storage (72 hours). On the 132\textsuperscript{nd} hours measurement, all carbohydrate substrates were used in oxidation of respiration process, which shown by the average RQ = 1 on control bananas and bananas coated with addition of 7\% CNF. Meanwhile, on bananas coated with addition of 5\% CNF, the RQ =1 on the 144\textsuperscript{th} measurement hour, which means that carbohydrate was only used in oxidation of respiration process on the sixth day of storage. Uncoated bananas and coated bananas without CNF addition (A0) show highest increase of RQ with the RQ > 10 at the end of storage time. High RQ value (RQ > 1) shows the existence of anaerobic respiration [15]. The normal RQ value was between 0.7 – 1.3 [15].

4. Conclusion
Nano cellulose concentrations within the starch matrix as edible coating in banana influences the TSS, color, weight loss, and respiration rate. Addition of 9\% CNF produces 13.5\% weight loss. Whereas, the lowest concentration of TPT is obtained on coating formula with 5\% and 9\% addition of CNF in sago matrix by 21.9\textdegree Brix and 22.9 \textdegree Brix, respectively. Also, addition of CNF in coating solution of sago starch can preserve color and reduce the respiration rate of the banana, hence, can slowdown the ripening of the coated bananas stored in room temperature.

Acknowledgements
The authors would like to thank LPDM and Gadjah Mada University trough RTA (Rekognisi Tugas Akhir) 2020 for financial support.

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