The Effects of Wrapping Paper Coated with Banana Flour on Physical Properties of Banana Fruit

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***Abstract*—Banana is one of the economic plants of Thailand, however, it undergoes rapid ripening which affects the short selling period. The utilization of paper wrapping application is used for respiratory reduction and retarding maturity to extend the selling and transportation period. The aims of this research were to study how bananas wrapped with paper coated with banana flour and zeolite or charcoal powder effect the physical properties and rate of carbon dioxide (CO_2) release compared to unwrapped bananas. The wrapped and control bananas were kept in room condition (30°C and 70%RH) for 6 days. The results showed that all the treatments were reduced in weight, firmness and CO_2 release but increased in Total Soluble Solid (TSS) and color difference (ΔE). The CO_2 content of wrapped bananas increased in the initial day of the storage and reduced after that. The zeolite and charcoal powder compound affected bananas with high weight loss and soft texture, moreover, black spots of charcoal powder caused high ΔE. Banana flour affected lower weight loss, CO_2 release and ΔE of the banana than the control bananas ($p<0.05$), but the firmness change of bananas wrapped with paper coated with banana flour was not significant different from the control bananas ($p>0.05$) which had lower changes than the others. Therefore, bananas wrapped with paper coated with only banana flour could maintain the quality of bananas in terms of weight, CO_2 release, firmness and ΔE during the storage.**

***Index Terms*—paper, wrapping, coating, banana**

I. INTRODUCTION

The banana (*Musa acuminata*, AAA group) is one of the major economic plant of Thailand. The 1,531 tons of bananas were exported, worth about 46.07 million Baht in 2016 [1]. Bananas are widely consumed in many countries because of their smell and taste, including their high nutrition. Bananas are considered to be a high energy food source due to the elevated levels of vitamin A, C, and E, β-carotene, and poly phenol, which are also related to high antioxidant capacity [2]. Bananas can be consumed fresh or processed to products such as banana powder, snacks, yogurt, frozen banana, dried banana, cake, cookies, candy, chips, dessert, sauce, juice, puree and flour [3]. Bananas are climacteric in their nature, which means that they undergo rapid ripening after harvest. The rates of oxygen (O_2) consumption, carbon dioxide (CO_2) evolution and ethylene production reach the peak value shortly after harvest; corresponding to the maximum ripeness, pleasant flavor, aroma and maximum eating quality of the fruit. Senescence occurs gradually after the climatic peak. The shelf-life of bananas is also limited by the postharvest fungal growth.

Paper is a biodegradable material that has been widely applied in the packaging sector because of its low cost. Wrapping paper is used to extend the shelf-life of postharvest fruits and vegetables because it reduces ethylene release and weight loss. It is composed of cellulose fibers crosslinks via hydrogen bonding. However, the hygroscopic cellulose and the porous fiber network cause the mechanical properties of paper to reduce or even disappear when exposed to moisture during the storage and transportation process [4]. It is still necessary to search for solutions to improve the mechanical properties, moisture and gas barrier properties, grease resistance as well as water absorption capacity because these properties directly influence the integrity and quality of packed products [5]. The coated paper sheet still acted positively to prevent the loss of moisture content and enhance gas permeability resistance of paper [6]. The polysaccharides-based coating material could potentially act as alternatives, to reduce the need for synthetic polymers, for the coating paper. The banana (*Musa sapientum*, ABB group) has abundantly starch. They are widely cultivated (80% of the bananas grown in in Thailand) and are for domestic consumption [1]. Bananas are low price tropical fruits with high nutrition. Moreover, they can be produced to local and commercial products. Because of their properties, the flour is used as raw material of pasta, noodle and bakery products [3]. Recently, utilization of natural materials has increased due to their antimicrobial activity and their safety [5].

The aim of this research was to study the effect of wrapping paper coated with banana flour (*Musa sapientum*) and coating additive (zeolite and charcoal powder) on the physical properties and carbon dioxide release of bananas compared to unwrapped bananas.

II. MATERIALS AND METHODS

A. Paper Coating and Wrapping Method

The banana flour solution was made from 4% green banana flour of *Musa sapientum* mixed with 1% zeolite

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and charcoal powder. The mixed solution was heated to 85°C for 10 min [3]. Then the coating material was obtained. The solution was applied on one side of the paper sheet (594 mm x 841 mm) by painting with a brush. The volume of the solution was controlled at 50 cm^3 per sheet (100 cm^3/ m^2, approximately). The coated paper was dried at room condition (30°C and 70%RH) for 2 h. The banana (*Musa acuminata*) at the 1st stage of maturation (green peel color) was purchased from Phonphisai district, Nong Khai, Thailand. The banana bunches were wrapped with one sheet of coated paper and then kept at room condition (30°C and 70%RH).

B. *Banana Determination*

Bananas wrapped with paper coated with 4% banana flour (BF), 4% banana flour and 1% zeolite (BFZ) and 4% banana flour and 1% charcoal powder (BFC) were determined every 3 days in terms of weight loss, firmness, color difference, total soluble solid and carbon dioxide release, which were changing during ripening. The control samples were unwrapped bananas. Bananas were determined until the peel color becomes brown and black more than 80% of all peel surface. All bananas were kept in room condition (30°C and 70%RH) which affected the shelf-life of banana was 5-7 days. All data was compared by one-way analysis of variance followed by Duncan multiple range test to determine differences among means with 95% significant.

1) *Weight loss of banana bunch*

Banana bunches were weighted every 3 days until the end of storage. Weight loss was calculated as follows:
%weight loss = (initial weight-current weight)*100/initial weight

2) *Firmness of banana fruit*

Banana firmness was determined using a firmness tester (model GY-3, Domestic Product, China). The diameter of puncher was 0.8 cm which compressed on 3 positions of the banana peel surface (top, middle and bottom). The firmness testing was replicated 3 times and recorded in kg/cm^2 unit.

3) *Total soluble solid (TSS) of banana pulp*

The TSS of the banana pulp was measured using a hand refractometer (model N-1α, Atago, Japan). The juice of banana was compressed and dropped on a prism of the hand refractometer. TSS was recorded in brix unit. The experiment was done at 25°C.

4) *Color difference (ΔE) of banana peel*

The color of the banana's peel was measured using a HunterLab spectrocolorimeter (model TC-P III A, Tokyo Denshoku Co., Ltd., Japan). Bananas with peel were measured on 3 positions which were top, middle and bottom of the banana fruits. The color of banana flour was reported in L*, a* and b* values, but the color of the banana peel was calculated into color difference (ΔE) which was calculated as follows:

$$\Delta E= (\Delta L^2+\Delta a^2+\Delta b^2)^{1/2}$$

5) *Carbon dioxide (CO_2) release from banana*

The tested bananas was put in a closed chamber with a CO_2 detector (model CO220, Extech instruments, Taiwan). The CO_2 was expressed in ppm and the data was recorded every 10 min until 1 h.

III. RESULTS

A. *Weight Loss of Banana Bunch*

The weight of the bananas decreased during the storage period in all treatments. The weight reduced because the moisture loss of calyx which was a destroying tissue [7]. The film forming ability of starch played a pivotal role in the moisture resistance of starch-coated paper because the bipolymer was compatible with the base paper and filled the pores of the porous structure [5]. On the 3rd day, they lost 10-15% weight and increased to 15-23% on day 6 of the storage except bananas wrapped with paper coated BF, thus, BF affected the weight loss protection (Fig. 1). It was a similar result from Battisti *et al.* [6] which expressed the gelatin coated papers acted positively to prevent the moisture loss from the beef to the atmosphere.

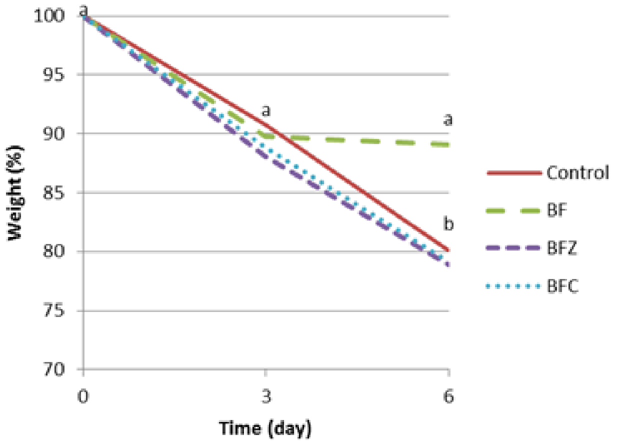

Figure 1. The weight of banana wrapped with paper coated BF, BFZ and BFC.

B. *Firmness of Banana Fruit*

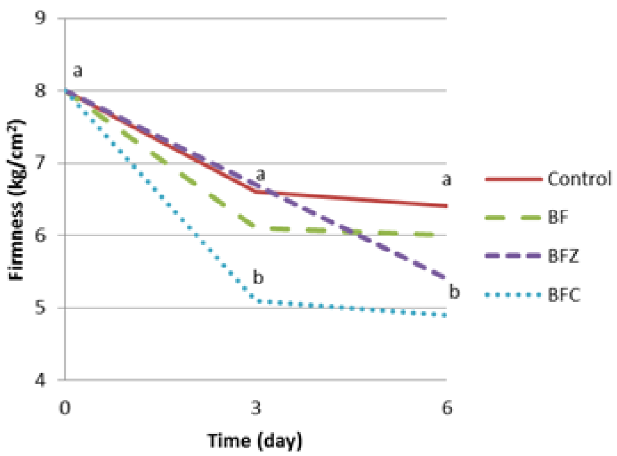

Figure 2. The firmness of banana wrapped with paper coated BF, BFZ and banana and BFC.

The firmness is an important parameter to determine the ripening stages and quality of banana fruits. Whereas ripening, pectinesterase and polygalacturonase hydrolyzed the pectin, leading to the destruction and deterioration of the cell wall structure, and in turn softened the fruits [8]. This phenomenon led to soft texture. The firmness of bananas decreased significantly on the 3rd day of the storage and slowly decreased thereafter (Fig. 2). The firmness of bananas wrapped with paper coated BF had no significant difference from control bananas (p>0.05). The previous study showed that the firmness of bananas coated with shellac/gelatin decreased due to depolymerization and deesterification of protopectin in middle lamella of the cell wall, which caused the softness [9]. The wrapping paper coated with BFZ and BFC was a barrier to stop water and gas, which was accumulated on the peel and caused firmness decrease, to pass through.

C. Total Soluble Solid (TSS) of Banana Pulp

Most of the TSS is sugar, which increases during the maturity stages, and causes the hydrolysis of starch and other carbohydrates. The TSS of banana wrapped with paper increased from 6 to 15-18 brix in day 6 of the storage because of the heat accumulation of air between fruits and paper whereas TSS of control bananas increased slowly (Fig. 3). The rate of respiration also increased due to the starch hydrolysis increase [9]. Compuzano *et al.* [10] reported the TSS of *Musa* AAA group was 2 brix in the 1st stage (totally green) and 18 brix in the 4th stage (more yellow than green) of maturity. This was different from lime because lime has no starch, the TSS of lime was the same through the storage period [11].

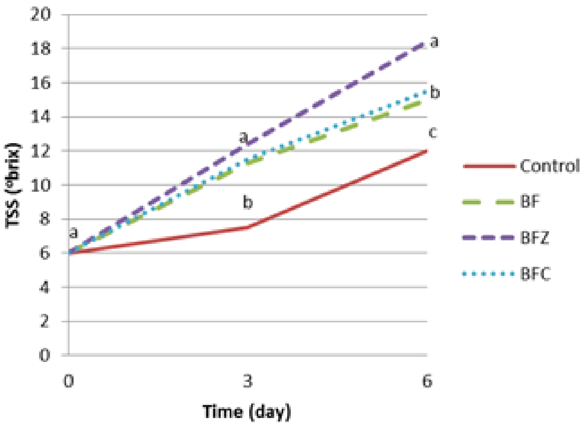

Figure 3. The TSS of banana wrapped with paper coated BF, BFZ and BFC.

D. Color Difference (ΔE) of Banana Peel

The peel color is the indicator of maturity of bananas which is important for harvesting. The raw bananas had green peel color which changed during ripening because the chlorophyll structure was destroyed [12] and then yellowness appeared, thereafter brown spots occurred. The phenol changed to quinin by polyphenol oxidase enzyme and polymerization caused the brown color [13]. In the experiment, the bananas in the 1st stage had green peel and was round with no corner. The peel color had changed in day 3 and slowly changing thereafter (Fig. 4-5). The peel color change was conformed to the respiration and moisture loss. The yellowness increased until brown spots occurred (Fig. 6). The wrapping paper coated BF and paper coated BFZ slowed down the chlorophyll degradation and reduced the incidence of browning spots on the bananas surfaces and this led to lower ΔE than the control ones (p<0.05) (Fig. 7). This was similar to mango coated with gum arabic [14] which was trifling changed compared to the uncoated one. The bananas wrapped with paper coated BFC has the highest ΔE. Because of their black spots, they are unpreferable for the consumers.

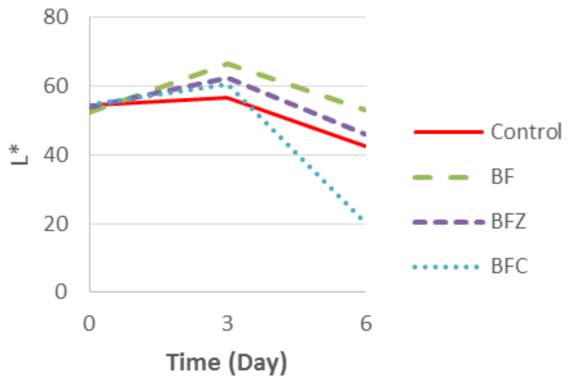

Figure 4. The L* of banana wrapped with paper coated BF, BFZ and BFC.

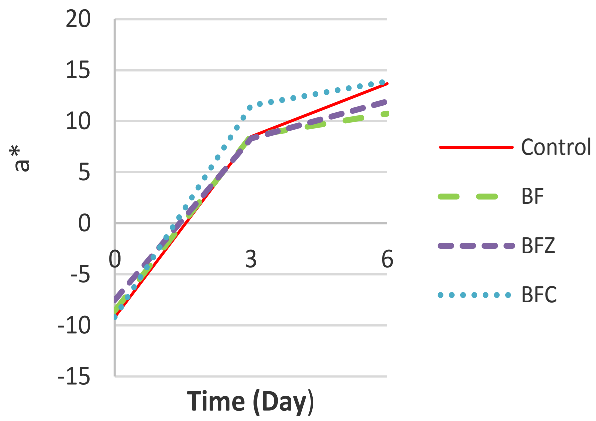

Figure 5. The a* of banana wrapped with paper coated BF, BFZ and BFC.

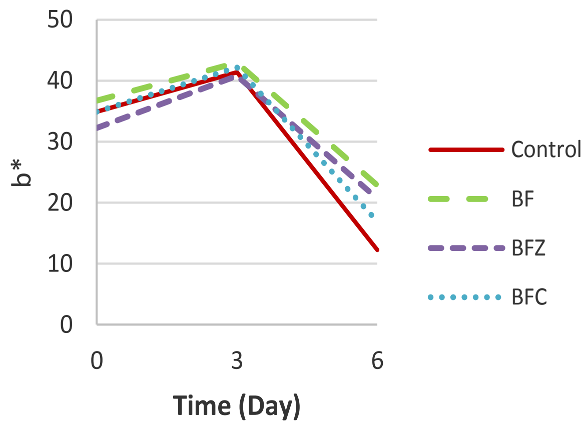

Figure 6. The b* of banana wrapped with paper coated BF, BFZ and BFC.

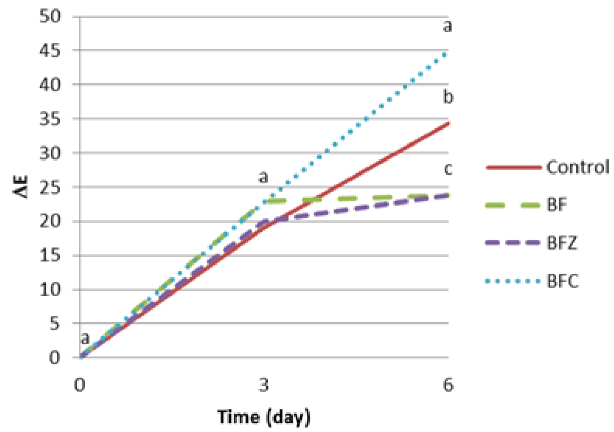

Figure 7. The ΔE of banana wrapped with paper coated BF, BFZ and BFC.

E. Carbon Dioxide (CO_2) Release from Banana Bunch

The CO_2 content of control bananas increased within the first 3 days. This conformed to the change of the peel color TSS and firmness which happened in the first 3 days of the storage. Whereas bananas wrapped with paper coated with BF, BFZ and BFC had high CO_2 release only at the initial day. Bananas wrapped with paper had limited O_2 for respiration. They adjusted themselves to the new condition. The CO_2 release decreased during the maturity stages. All the treatments had lower CO_2 release than the control bananas ($p<0.05$). In day 6, there were no significant difference between the wrapped bananas from each treatment ($p>0.05$) (Fig. 8). The banana coating compound had the efficiency to reduce CO_2 release, similarly to the soy protein coating compound which reduced CO_2 production of fresh-cut mango. Generally, polysaccharide and protein coating could reduce respiration rate of fruits and vegetables [15].

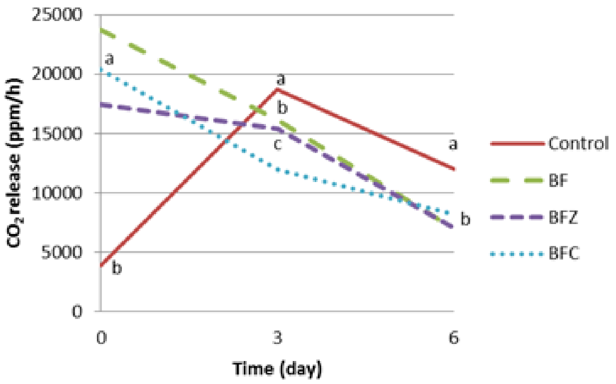

Figure 8. The CO_2 release of banana wrapped with paper coated BF, BFZ and BFC.

IV. Conclusion

Bananas wrapped with paper coated with banana flour maintained the quality in terms of weight, CO_2 release, and color difference during the storage. Moreover, the shelf-life could extend to 9 days with slight change of quality. The zeolite and charcoal powder compound affected high weight loss and soft texture, moreover, the black charcoal powder caused high ΔE.

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