MATURITY ASSESSMENT OF CAVENDISH BANANAS (*Musa paradisiaca* L.) USING THE THERMAL IMAGE METHOD

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ABSTRACT

Bananas (*Musa paradisiaca* L.) is a climacteric fruit having short storing period and fast fruit quality decrease. Maturity stage of banana fruit is an important factor that influences the fruit quality, so that the maturity level to determine proper harvesting time is required. Harvesting of banana fruit based on the fruit physical characteristics such as diameter and days after anthesis is considered to be less precise. The objective of this research was to find out the influence of banana fruit diameter to it's maturity level that was detected by thermal image method. This research was conducted using three fruit maturity levels based on their diameter; small diameter (<38), medium diameter (38-42), and large diameter (43-48) with skim scale at stage I. That scale was commonly used to determine quality standard size of Cavendish bananas, especially for international trade. The result showed that the increasing of fruit maturity level was followed by decreasing of firmness and increasing of fruit weight, °Brix, free acid, and sucrose. Thermal image method is potentially used to detect the fruit maturity level where increasing of fruit size was followed by rising of temperature.

***Keywords**: fruit maturity, Cavendish banana, thermal image*

INTRODUCTION

Banana (*Musa paradisiaca* L.) is one of fruit commodities that is consumed many people since it contains fiber, vitamin, magnesium, and has a lower fat. In Indonesia, one of the superior banana cultivars for international trade is Cavendish banana. This type of banana is officially recognized by Ministry of Agriculture based on Decree of Minister of Agriculture No. 702/Kpts/SR.120/5/2008 (Ministry of Agriculture, 2008). Banana fruits is classified as a climacteric fruit with short storing period and fast fruit quality decrease because of their respiration and transpiration activities and high ethylene production during storage.

Banana fruit harvest timing based on the fruit physical characteristics such as diameter and days after anthesis is considered to be less precise, because the same fruit physical form may produce different possibilities of physiological maturity levels, and fruit physical form alone cannot describe all physiological effects to detect fruit maturity level in the very beginning. The banana fruit maturity level is an important factor that influences the fruit quality, so that a proper timing determination for harvesting is required. The fruit maturity level detection for determining Cavendish bananas harvest timing is done with thermal image method.

Thermal image is a non-contact technology that measures infrared wave emanated from an object to detect temperature distribution. It is also known as a non-destructive method to detect the maturity level of Cavendish bananas without damaging it. Salankar and Ansari (2017) suggested that thermal image method could be used to analyze banana fruit maturity condition. Thermal image could also be used to identify both natural and artificial banana fruit maturities with high accuracies (Karthika *et al.*, 2017). These researches suggested the potential of thermal image used in identifying banana fruit maturity. However, banana fruit physiological maturity stages that are divided into three diameter size scales are not yet studied, despite of precise physiological maturity determination becoming an important criterion in determining banana fruit quality. The objective of this research was to find out the effect of banana fruit diameter to the maturity level of banana detected by thermal image method.

METHODS

This research was conducted at the Horticulture Postharvest Laboratory, The Department of Agrotechnology, Faculty of Agriculture, University of Lampung in April 2021. Materials used in this research were Stage I Cavendish bananas (green) obtained from PT Nusantara Tropical Farm (NTF Co.), East Lampung District, Lampung Province. The samples were classified into three diameter sizes; small (<38), medium (38-42), and large (43-48) with skim scale. Equipments used in this research were thermal image camera (FLIR F5–XT, ± 2 ^{0}C accuracy, resolution 160x120 pixels, thermal sensitivity < 0.10 ^{0}C), imaging chamber, computer, Matlab (R2014a), scale, penetrometer, ‘Atago’ hand refractrometer, and thermometer.

Cavendish bananas samples were prepared, weighed, and stored overnight at temperature of 26-28 ^{o}C to keep the fruit temperature stable. Prepared sample objects were taken for thermal image one by one in the chamber at 25 cm distance between the infrared camera and object. There were 10 samples for each diameter as repetition. Each sample unit was taken for image at three times. Thermal image analysis was done by using Matlab (R2014a) and by reading temperature displayed in the middle section of the fruit. Variables of fruit maturity level characteristics to be observed were temperature, weight, firmness, soluble solid

(°Brix), sucrose, free acid, and starch of the fruit. Results of physical and chemical quality observations were correlated with thermal image analysis results by using regression score (R^2). Data of temperature, weight, firmness and °Brix were analyzed by using analysis of variance (ANOVA) and followed with least significant difference test (LSD) at critical values for α 5% and 15% (Statistic 8).

RESULT AND DISCUSSION

Cavendish bananas analysis was conducted when the fruit was at stage I (green) by correlating fruit temperatures from difference fruit maturity levels to the fruit physical and chemical qualities. The applied thermal image method could show temperature differences. Fruit temperature increased from the small to large diameter of the fruits. This phenomenon indicated that the more mature of the fruit, the higher the fruit temperature. Cavendish banana with large diameter had temperature of 29.15 °C, while the medium diameter 28.88 °C and small diameter 28.85 °C (Table 1). The thermal image method indicated that the larger and the more mature of fruits, the more heat was accumulated (Stajnko *et al*., 2004).

Tabel 1. Fruit temperature and physical quality of Cavendish bananas at three levels of maturity

Maturity Levels	Fruit Temperature (°C)		Weight (gram)		Firmness (kg/cm^2)	
	(α=5%)	(α=15%)	(α=5%)	(α=15%)	(α=5%)	(α=15%)
Small diameter (< 38)	28.85 b	28.85 b	374.70 b	374.70 c	5.84 a	5.84 a
Medium diameter (38−42)	28.88 b	28.88 b	501.07 b	501.07 b	5.09 a	5.09 ab
Large diameter (43−48)	29.15 a	29.15 a	686.47 a	686.47 a	4.11 a	4.11 b
Regression coefficient (R^2) to the fruit temperature			0,8872		0,8661	

Notes: The numbers followed by different letters in the same column are significantly different at the 5% and 15% LSD tests

Based on the physical qualities, banana fruit with a higher level of maturity would be followed by increase of weight and decrease of fruit firmness. The fruit with larger diameter had higher fruit weight by 686.47 gram, while the fruits with medium diameter have a weight of 501.07 gram and small diameter 374.70 gram (Table 1). Maturity process was followed by decreasing firmness while the fruit flesh become softer. Cavendish bananas with large diameter had lowest firmness score by 4.11 kg/cm^2, compared to medium diameter (5.09 kg/cm^2), and small diameter size (5.84 kg/cm^2) (Table 1). Widodo *et.al* (2019) suggests that fruit maturity improvement is generally followed with fruit skin and flesh softening. The higher fruit skin and flesh softening level would indicate more mature fruit. Fruit firmness change is caused by soluble protopectin degradation, so that during fruit maturing many bio-chemical and structural changes occur (Praja *et al*., 2021).

Analysis of variance was done and followed by least significant difference test for each physical parameter and the result showed that the fruit maturity level classification was presented significantly by weight variable at significant value of α = 0.05 and α = 0.15. Meanwhile fruit firmness was presented significantly at significant value α = 0.15 (Table 1). Thermal image method application (sensoring) at fruit temperature could follow fruit maturity level changes. The correlation between emanated temperature and fruit weight and firmness showed a high correlation (R^2 > 0.86).

Table 2. Fruit temperature and chemical quality of Cavendish bananas at three levels of maturity

Maturity Levels	Fruit Temperature (°C)		°Brix (%)		Sucrose (%)	Free Acid (%)	Starch (%)
	(α=5%)	(α=15%)	(α=5%)	(α=15%)			
Small diameter (< 38)	28.85 b	28.85 b	8.76 a	8.76 b	1.57	0.71	4.30
Medium diameter (38−42)	28.88 b	28.88 b	9.11 a	9.11 ab	3.99	1.52	3.26
Large diameter (43−48)	29.15 a	29.15 a	10.50 a	10.50 a	6.93	2.19	4.23
Regression coefficient (R^2) to the fruit temperature			0.8872		0.8511	0.7661	0.1490

Notes: The numbers followed by different letters in the same column are significantly different at the 5% and 15% LSD tests

Fruit maturity level improvement was followed by increases of soluble solid content (°Brix), sucrose, and free acid. Meanwhile, starch content did not correlate to fruit maturity level (Table 2). Cavendish bananas with large diameter size had a highest soluble solid content (°Brix) by 10.50%, compared to medium diameter size (9.11%), and small diameter size (8.76%) (Table 2). The soluble solid content (°Brix) increase could be caused by increased respiration rate at maturity process, so that complex material degradation such as carbohydrate caused starch content decrease and sucrose increase (Praja *et al*., 2021). This was followed with sucrose increase along with more mature fruit condition. The banana fruit with large diameter size had higher sucrose content by 6.93%, compared to medium diameter size (3.99%), and small diameter size (1.57%) (Table 2). Research result by Zhu et. al (2021) shows starch conversion into sucrose during fruit maturity process. Banana maturity process is followed by fruit softening and fruit sweetness is mostly caused by starch degradation. At the green stage, bananas have very high starch content and a low amount of sugars, which changes dramatically to high sugars and low starch at the full-ripe stage (Evans *et al*., 2020).

The research result also showed free acid content increase at Cavendish bananas. The banana fruit with small diameter size had lowest free acid content by 0.71% compared to miedium diameter size (1.52%) and large diameter size (2.19%) (Table 2). Widodo et. al (2019) suggests that banana fruit undergoes free acid increase during fruit maturity process. Citric acid and malic acid are not affected by plant culturing technique, but they are affected by genotype and plant age to harvest (Etienne *et al.*, 2014).

The least significant difference test of Cavendish bananas chemical quality variable indicated no significant difference at significant level of α 5%, but it showed significant difference of fruit maturity level at significant level of α = 15%. The correlation of chemical quality variable (°Brix, sucrose, and free acid) to varying fruit maturity levels showed a high correlation value ($R^2 > 0.76$). Meanwhile, the correlation between fruit temperature and starch content was weak ($R^2 = 0.1490$). Therefore, infrared sensoring was potential to use for detecting Cavendish bananas maturity level.

CONCLUSION

The conclusion of this research was that thermal image method was able to detect different fruit maturity levels of stage I Cavendish bananas. The diameter size increase was followed by the fruit temperature level. The Cavendish bananas temperatures were 28.85 ^{o}C at small diameter size, 28.88 ^{o}C at medium diameter size, and 29.15 ^{o}C at large diameter size. The banana fruit maturity level was followed by increases of fruit weight, soluble solid content (°Brix), sucrose, and free acid. The banana fruit maturity level was followed by fruit firmness score decrease.

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