

# Detection of Fruit Maturity of 'Cavendish' Banana by Thermal Image Processing Technique

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**Abstract.** The level of fruit maturity for determining harvest time is an important factor that affects fruit qualities during ripening of 'Cavendish' banana. The quality resulting from that process can affect the level of consumer acceptance. During growth, fruit undergoes metabolism which produces energy and emit some kinds of infrared radiation. The thermal image processing technique was tried to detect fruit temperature at various levels of maturity of the fruits. Five bunches of 'Cavendish' bananas, with 8 hands each, from the top to the eighth hand were used for the experiment. Four fingers of each hand were analyzed for their thermal images, physical quality, chemical quality, and SEM. Each bunch was used as replications in the analysis. The standard method of determining the level of fruit ripeness was carried out to find the correlation with the thermal image. The results showed that the thermal image could distinguish the level of maturity and ripening, both the level of maturity between each hand on bunches of 'Cavendish' bananas and bananas in the ripe and mature phases. Thermal image results had a close correlation with physical (weight, diameter, fruit firmness) and chemical qualities (glucose, sucrose, starch) but had no correlation with fruit surface conditions (scanning electron microscope), °Brix and free acid contents based on regression value. The hand at the top of the bunch had a higher temperature, which was 28.91°C compared to the hand at the bottom, which was 28.71°C. Cavendish bananas on day 7 (ripe) had a higher temperature of 29.17°C compared to bananas on day 1 (unripe) which was 28.92 °C.

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

## Introduction

As a climacteric fruit, 'Cavendish' banana fruit is harvested based on physical characteristics, namely based on the diameter of the banana finger fruit in the middle second hand as measured by a skimming tool with a minimum number of 38. This skimming number indicates that the fruit is ready to be harvested, aged 8-11 weeks after bagging, with a maturity level reaching 75-80% mature [1]. This level of maturity is estimated to be in the phase before the fruit reaches physiological maturity, so that theoretically the fruit will not ripen naturally. Therefore, during shipment for export in refrigerated containers, the 'Cavendish' bananas are expected not to ripen, and will only ripen if stimulated with ethylene after the fruit has arrived at its destination. Arriving at the export destination, the unripe bananas

will be gassed with ethylene until they reach maturity stage III (greenish yellow fruit skin), and are ready to be marketed.

Based on data in the field (R. A. Wardhana, Great Giant Foods, Co. Ltd., Terbanggi Besar, Central Lampung, Indonesia; personal communication) incidents of ripe Cavendish bananas on the way during export (early ripening) often occur with varying volumes. Other researchers [2] refer to it as "mixed ripe", which is the term given to fruit that is sent to the market in a green condition but some of them have started to ripen (ripe) by the time they arrive at the market. This condition makes it difficult for artificial ripening and marketing and is detrimental to farmers or exporters. If this happens, the bananas will be rejected, causing significant material and non-material losses for exports. This happens because the harvest criteria are carried out physically, where fruits with the same physical criteria may have different levels of physiological maturity [2]. Climacteric fruit that has reached physiological maturity (full mature fruit) will naturally ripen perfectly. This occurrence is undesirable in 'Cavendish' banana exports. To overcome the problem of premature ripening of 'Cavendish' bananas as a result of harvesting based on physical properties, a more effective way is needed to distinguish the maturity level of 'Cavendish' bananas, one of which is using thermal image.

Thermal image (TI) is a non-invasive, non-contact and non-destructive technology used to determine the thermal properties and features of various objects. Potential uses of thermal in agriculture include nursery and greenhouse monitoring, irrigation scheduling, detection of plant diseases, estimation of fruit yield, evaluation of fruit maturity and detection of damage (bruising) on fruits and vegetables [3, 4]. This study, therefore, aimed to analyze the various levels of fruit maturity of 'Cavendish' banana fruit with the thermal image method and obtain a thermal image correlation with the physical and chemical qualities of the fruits.

## **Materials and Methods**

This research was conducted by bringing in 10 bunches of 'Cavendish' banana fruit (stadium I; as a fresh harvest with standard maturity) from Great Giant Food, Co. Ltd. (GGF) in Terbanggi Besar, Central Lampung, Indonesia. From the 10 bunches, 5 bunches of the bananas with relatively uniform in size were selected. The banana hands were then separated from the bunches and coded the sample according to the order of the hands from the top of the bunches, for example, H1R1 (1<sup>st</sup> hand, 1<sup>st</sup> replication) to H8R5 (8<sup>th</sup> hand, 5<sup>th</sup> replication). Then, from each hand, 4 finger bananas were taken to be used for SEM (scanning electron microscope) analysis, thermal image, chemical (<sup>o</sup>Brix, free acid, glucose, sucrose, starch), and physical (fruit weight, diameter, and firmness) qualities.

Thermal image (TI) observations were carried out by maintaining room temperature at 28 °C, and there was no physical contact with the fruit when taking pictures to avoid local heat transfer to the fruit. TI was analyzed periodically every two days until the bananas were ripen. The data of physical and chemical fruit qualities were processed using the Statistix 10 with the Least significant difference test (LSD) at the level of 5% and 15%. The results of the TI and scanning electron microscope (SEM)

were processed using the Image J & MATLAB. The physical and chemical quality observations were then correlated with the data of the TI and presented with the regression value ( $R^2$ ).

## Results and Discussion

This study was conducted to determine the correlation of thermal image data from various levels of fruit maturity to the physical and chemical quality of 'Cavendish' bananas. The results showed that there were differences in the temperature of each finger of the 'Cavendish' banana (Table 1).

**Table 1.** Thermal image (TI) of 'Cavendish' banana fingers in room temperature based on the maturity levels of banana hands during ripening\*.

Maturity level**	1 <sup>st</sup> Day (°C)		3 <sup>rd</sup> Day (°C)		5 <sup>th</sup> Day (°C)		7 <sup>th</sup> Day (°C)	
	5%	15%	5%	15%	5%	15%	5%	15%
H1	28.91 a	28.91 a	28.83 a	28.83 a	28.93 a	28.93 a	29.17 a	29.17 a
H2	28.89 a	28.89 ab	28.72 ab	28.72 ab	28.85 ab	28.85 a	29.13 a	29.13 ab
H3	28.85 a	28.85 abc	28.70 ab	28.70 b	28.84 ab	28.84 ab	29.11 a	29.11 ab
H4	28.83 a	28.83 abc	28.70 ab	28.70 b	28.70 bc	28.70 bc	29.09 a	29.09 ab
H5	28.77 a	28.77 abc	28.68 ab	28.68 b	28.69 bc	28.69 c	29.02 a	29.02 ab
H6	28.76 a	28.76 abc	28.67 ab	28.67 b	28.67 bc	28.67 c	28.97 a	28.97 ab
H7	28.74 a	28.74 bc	28.65 ab	28.65 b	28.66 bc	28.66 c	28.93 a	28.93 ab
H8	28.71 a	28.71 c	28.63 b	28.63 b	28.60 c	28.60 c	28.92 a	28.92 b

\*The mean values followed by the same letters are not significantly different according to the LSD test at the level of 5% and 15%; \*\* H1-8 = first to eighth hands, respectively, from the top bunch of 'Cavendish' bananas.

In Table 1, it appears that overall there was a tendency of decreasing in temperature from H1 to H8; the lower the hand order, the lower the temperature. However, this tendency was not detected as a significant decrease in temperature until the LSD level was increased up to 15%. In addition, it can be seen that the results of the thermal image have a significant effect on all treatment levels (BNT: 15%) and have a significant effect on the 3rd and 5th day (BNT: 5%). On the 1st day of treatment H1 had the highest temperature, which was 28.91°C and H8 with the lowest temperature, which was 28.71°C. This shows an indication that the 'Cavendish' bananas on the top hand had a higher temperature than the bottom hand during the ripening process. In Table 1, it also shows that the temperature of H1 on the 7<sup>th</sup> day (ripe), which was 29.17°C higher than the temperature of H1 on the 1<sup>st</sup> day (unripe), which is 28.91°C. Other researchers noted similar tendencies [3] that there was a gradual increase in fruit temperature over time, the temperature of bananas during the ripening process was 19°C on the 1<sup>st</sup> day to 25°C on the 5<sup>th</sup> day which was recorded by the thermal image. Other studies also stated that ripe fruit had a higher heat capacity than unripe fruit [5].

In Table 2, it appears that the data of the thermal image had a close correlation with fruit physical qualities, namely fruit weight, diameter, and fruit hardness based on the regression value ( $R^2$ ). In

addition, it can be seen that the data of the thermal image had a significant effect on all observation variables, both in the LSD tests of 5% and 15% levels. In general, bananas on the top hand had a higher weight, diameter, and temperature than the hand below.

**Table 2.** Finger weight, diameter, and firmness of ‘Cavendish’ banana at 1<sup>st</sup> stadium according to maturity levels of banana hands.

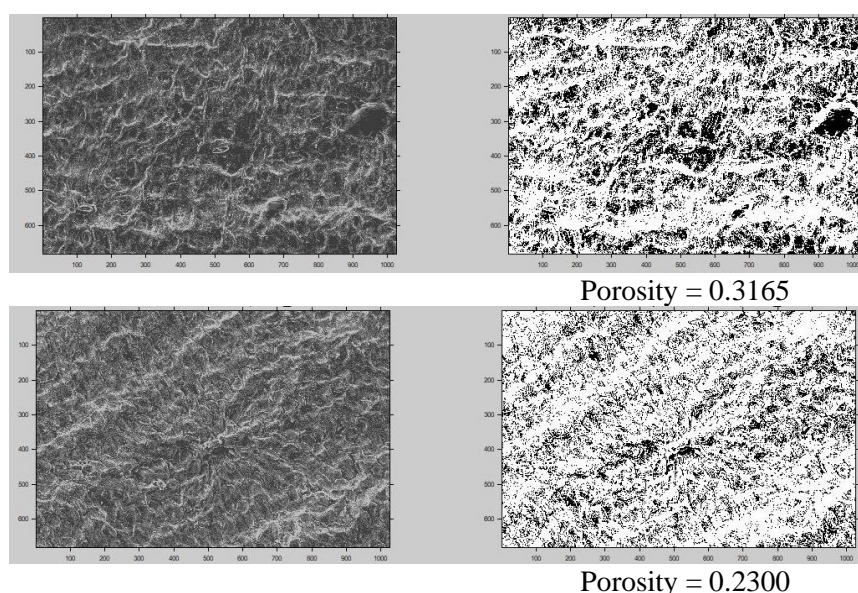
<i>Maturity level</i>	Fruit Weight (g/finger)		Fruit Diameter (mm)		Fruit Firmness* (kg/cm <sup>2</sup> )	
	5%	15%	5%	15%	5%	15%
H1	193.04 a	193.04 a	36.58 ab	36.58 abc	1.53 d	1.53 e
H2	193.64 a	193.64 a	36.98 ab	36.98 ab	1.95 cd	1.95 d
H3	179.94 ab	179.94 a	38.11 a	38.11 a	2.21 c	2.21 d
H4	161.70 bc	161.70 b	37.08 ab	37.08 ab	2.92 ab	2.92 bc
H5	148.62 cd	148.62 b	35.59 abc	35.59 bc	2.74 b	2.74 c
H6	126.42 de	126.42 c	34.98 bc	34.98 cd	3.05 ab	3.05 abc
H7	113.08 ef	113.08 c	33.12 cd	33.12 de	3.36 a	3.36 a
H8	89.22 f	89.22 d	32.30 d	32.30 e	3.20 a	3.20 ab
R <sup>2</sup> to TI	0.9348	0.9348	0.7139	0.7139	0.8439	0.8439

\*The mean values followed by the same letters are not significantly different according to the LSD test at the level of 5% or 15%; \*\* H1-8 = first to eighth hands, respectively, from the top bunch of 'Cavendish' bananas; R<sup>2</sup> to TI = Coefficient of correlation to 1<sup>st</sup> day thermal image in Table 1.

Table 2 also shows that there was an increase in the firmness values of bananas from the top hand (H1) to the bottom hand (H8). This was because the bananas on the top hand were more mature so they were softer than the hand underneath. When seen in Table 2, 'Cavendish' banana on the 8th hand had a higher firmness value, which was 3.20 (kg/cm<sup>2</sup>) than the 1st hand with a firmness level of 1.53 (kg/cm<sup>2</sup>). Working with 'Barangan' banana, other researchers [6] stated that during the ripening process, several changes occurred including changes in fruit tenderness, an increase in the level of fruit maturity which was generally followed by a process of softening the skin and flesh of bananas. The opposite tendencies occurred at fruit temperature where the fruit on the upper hand had a higher temperature than the hand below (Table 1). The results of other researcher's [7] showed that most of the fruit and vegetable commodities had a negative temperature coefficient indicating that the firmness decreased with increasing temperature.

Physical quality observations were also carried out on the fruit surface using a Scanning Electron Microscope (SEM) which can be seen in Figure 1. Figure 1 shows that 'Cavendish' bananas that were approaching harvest time have flat and elongated epidermal cells parallel to the circumference of the fruit, when the fruit is about to ripen (ripe) there will be a separation between the epidermal cells, the magnitude of the separation between epidermal cells can be expressed in terms of porosity. The SEM showed that H1 has a higher porosity value, which was 0.3165 compared to the porosity value of H8, which was 0.2300. Researchers [8] showed that ripe fruit cracked higher than that of mature fruit (unripe), symptoms of cell separation and cracks between cells arise due to the inability of cuticle and epidermal cells to develop at the same rate as cells underneath.

Based on the observational data shown in Table 3, it appears that the data of thermal image had a close correlation with sucrose, glucose and starch but did not correlate with the free acid content and total soluble solids (°Brix). In addition, the results of chemical analysis had a significant effect on all treatment levels on LSD 15% and significantly affected soluble solids, free acids, and starch on LSD 5%. The sugar contents (glucose and sucrose) of the top hand (H1) was higher, namely 0.81% and 0.44%, compared to the 8<sup>th</sup> hand (H8), which was 0.64% and 0.35% followed by a decrease in the temperature of the 'Cavendish' bananas. This was in accordance with previous research [9] which states that the sugar content will increase when the fruit was ripe. When the process was leading to ripening, there was a change in the color of the banana followed by a change in texture to become soft, the sugar content increases, while the starch decreases [9]. The starch content decreased with the maturity level of the fruit (Table 3), the more ripe fruit on the 1<sup>st</sup> hand (H1) had a higher starch content than the lower hand.



**Figure 1.** Analyses on 'Cavendish' banana finger rind of 1<sup>st</sup> (two uppers) and 8<sup>th</sup> (two lowers) hands from the top bunch with scanning electron microscope (SEM; 5000 x).

**Table 3.** °Brix, acidity, glucose, sucrose, and starch contents of 'Cavendish' banana fingers at 1<sup>st</sup> stadium according to maturity levels of banana hands.

Maturity level	°Brix* (%)		Acidity (%)		Glucose (%)		Sucrose (%)		Starch (%)	
	5%	15%	5%	15%	5%	15%	5%	15%	5%	15%
H1	3.92 a	3.92 a	1.83 a	1.83 a	0.81 a	0.81 ab	0.44 a	0.44 ab	4.37 ab	4.37 a
H2	3.7 ab	3.7 ab	1.64 ab	1.64 a	1.00 a	1.00 a	0.27 a	0.27 b	2.45 b	2.45 b
H3	3.64 ab	3.64 abc	1.08 b	1.08 b	0.55 a	0.55 b	0.35 a	0.35 ab	5.07 a	5.07 a
H4	3.54 ab	3.54 abc	1.95 a	1.95 a	0.74 a	0.74 ab	0.53 a	0.53 ab	4.44 ab	4.44 a
H5	3.62 ab	3.62 abc	1.54 ab	1.54 a	0.79 a	0.79 ab	0.72 a	0.72 a	4.36 ab	4.36 a
H6	3.24 b	3.24 c	1.71 a	1.71 a	0.66 a	0.66 ab	0.45 a	0.45 ab	3.86 ab	3.86 ab
H7	3.32 ab	3.32 bc	1.57 ab	1.57 a	0.66 a	0.66 ab	0.39 a	0.39 ab	3.97 ab	3.97 ab
H8	3.58 ab	3.58 abc	1.50 ab	1.50 ab	0.64 a	0.64 ab	0.35 a	0.35 ab	3.53 ab	3.53 ab
R <sup>2</sup> to TI	0.4885	0.4885	0.0222	0.0222	0.8767	0.8767	0.8162	0.8162	0.8654	0.8654

\*The mean values followed by the same letters are not significantly different according to the LSD test at the level of 5% or 15%; \*\* H1-8 = first to eighth hands, respectively, from the top bunch of 'Cavendish' bananas;  $R^2$  to TI = Coefficient of correlation to 1<sup>st</sup> day thermal image in Table 1.

In general, the lower the hand order, the lower the soluble solid ( $^{\circ}$ Brix) and free acid contents. 'Cavendish' bananas on the 1st hand (H1) had higher  $^{\circ}$ Brix and free acids contents, namely 3.92% and 1.83%, compared to the 8<sup>th</sup> hand (H8) bananas, namely 3.58% and 1.50% (Table 3), followed by a decrease in the temperature of 'Cavendish' bananas (Table 1). This was in line with [10] stating that the total dissolved solids content increases with fruit development and the total acid content contained in the fruit including ascorbic acid tends to increase during the fruit ripening process due to the decarboxylation process of oxalic acid.

## **Conclusion**

The results showed that the thermal image could distinguish the level of maturity and ripening, both the level of maturity between each hand on bunches of 'Cavendish' bananas and bananas in the ripe and mature phases. Thermal image results had a close correlation with physical (weight, diameter, fruit firmness) and chemical qualities (glucose, sucrose, starch) but had no correlation with fruit surface conditions (scanning electron microscope),  $^{\circ}$ Brix and free acid contents based on regression value. The hand at the top of the bunch had a higher temperature, which was 28.91 $^{\circ}$ C compared to the hand at the bottom, which was 28.71 $^{\circ}$ C. Cavendish bananas on day 7 (ripe) had a higher temperature of 29.17 $^{\circ}$ C compared to bananas on day 1 (unripe) which was 28.92  $^{\circ}$ C.

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## **References**

- [1] Hameed F A R A A 2008 *Evaluation of William's Banana (Musa Cavendish L.) Clones Under Hot Arid Climates of the Sudan* (Thesis) Department of Horticulture, Faculty of Agriculture, University of Khartoum. 294 p
- [2] Santosh D T, Tiwari K N and Reddy R G 2017 *Int. J. Curr. Microbiol. App. Sci.* **6(7)** 1275-1291
- [3] Gurupatham S, Fahad K and Adam H 2018 *Improving Shelf-Life of Fruits Using Thermography*. Kennesaw State University, Georgia
- [4] Ishimwe R, Abutaleb K and Ahmed F 2014 *Advances in Remote Sensing J.* **3** 128-140
- [5] Sumriddetchkajorn S, and Yuttana I 2018 Two-Dimensional Fruit Ripeness Estimation using Thermal Imaging. *Proc. of SPIE International Conference on Photonics Solutions*. Pattaya: 26-28 May 2013. 8883 1C
- [6] Widodo W D, Ketty S, and Rizky R 2019 *Bul. Agrohorti.* **7** 162-171
- [7] Malcom C B 1982 *J. Food Sci.* **42** 440-444
- [8] Williams M H, Vesik M, and Mullins M G 1989 *Can. J. Bot.* **67** 2154-2160

- [9] Harefa W, and Usman P 2017 *Jurnal Faperta* **4** 1-12 (Indonesian with English Abstract)  
[10] Lee S K, and Kader A A 2000 *Post\_ Biol\_ Technol.* **20(3)** 207-220