Physiological characteristics of postharvest Barangan banana based on harvest time differences

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Abstract. Barangan banana is a local variety, included in climacteric fruit. The purpose of this study is to determine the optimum storage time based on the physiological characteristics of postharvest Barangan banana on harvest time differences. Samples are used 10 (P10), 11 (P11), 12 (P12) week after cutting banana heart, stored at room temperature (25±2 °C), RH ±85% for 15 days. Measurements of respiration rate and ethylene were carried out for 6 days in a continuously closed chamber. Air samples in the chamber were taken every 3 hours through headspace as much 1 ml to be analyzed. Results showed that sample P12 was stimulated by ethylene earlier changed the respiration rate faster than another. The brightness level (L*), P11, and P12 get a peak value on the 6th day, while the P10 continues to increase until the 15th day. The hue value for P12 occurred the fastest yellow change, then approached black color after day 12th, whereas P10 and P11 turn yellow later than P12 but still maintain yellow until the 15th day. The level of firmness, all samples get a decrease in the level of firmness until the 15th day. TSS at P12 gets a change in peak on the 6th day, while P10 and P11 get a peak on the 12th day. The optimum storage time for P12 is 6 days, while P10 and P11 are 12 days after harvest.

1. Introduction
Barangan banana is a local variety from Indonesia. Barangan banana has distinctive aroma and taste characteristics. Barangan banana is included in a group of climacteric fruits, which has high respiration rates and endogenous ethylene production after harvest. The presence of endogenous ethylene is a form of expression of a changed gene in the advanced stages of the fruit maturation process [1,2]. The maturation process can be identified by structural changes in fruit after harvest. The maturation process involves physiological and biochemical changes that can be observed indirectly. The change that occurred, such as transpiration, respiration, rate of ethylene production, softening, and changes fruit composition.

Changes in postharvest physiology affect the duration of storage and fruit quality. In the study [3], banana stored at room temperature (25±2 °C) only lasted about 7-8 days. The acceleration of maturity is undesirable by farmers because the shelf life of fruit becomes short. Estimates [4], state that about one-third of all banana fruit produces has never been consumed by humans. This case often occurs in developing countries such as Indonesia. Therefore, postharvest knowledge of fruit is a major requirement for farmers to reduce postharvest losses.

Proper harvesting time is the main key for barangan banana farmers to estimate the duration of storage and distribution of fruit. The difference in harvesting time certainly affects the duration of storage and fruit quality after harvest. In this study, the optimum duration of storage time is assessed based on the fruit quality characteristics of the different
harvesting time. The purpose of this study is to determine the optimum storage time based on
the physiological characteristics of postharvest Barangan banana on harvest time differences.

2. Materials and methods
Samples were used Barangan bananas from PTPN VIII Parakansalak, Sukabumi. The ages of
fruit harvest were 10 weeks after cutting banana heart (P10), 11 weeks after cutting banana
heart (P11), and 12 weeks after cutting banana heart (P12) based on the harvest ages, which
has determined by the farmer or PTPN VIII. This research did at the Laboratory of Food
Processing and Agricultural Products (TPPHP) Department of Mechanical and Biosystem
Engineering, IPB University.

Barangan bananas were tested based on the rate of endogenous ethylene (C$_2$H$_4$)
production, as measured by Gas Chromatography (GC). GC can detect specific gas for every
air flowed into the tube column of GC. It used for specific ethylene gas from the chamber
that flowed into the tube column of GC. Respiration rate for oxygen (O$_2$) and carbon dioxide
(CO$_2$) were measured by Gas Analyzer. It was used for specific gas oxygen (O$_2$) and carbon
dioxide (CO$_2$).

The quality analysis was examined the color change by Chromameter Minolta CR-300.
The firmness changes were measured by Rheometer CR-300. The total soluble solids (TSS)
changes were measured by hand-held Refractometer ATAGO. Samples were stored at room
temperature (25±2 °C) in humidity ±85% for 15 days for all samples at different harvest
times.

2.1. Endogenous ethylene measurement
Barangan bananas were put in a continuously closed chamber. Air samples in the chamber
were taken every 3 hours through headspace as much as 1 ml to calculate endogenous
ethylene concentrations. Gas uptake was done periodically every 3 hours for 144 hours of
observation. The ethylene production rate was calculated by the following equation.

$$ R_{C_2H_4} = \frac{([y_{C_2H_4}(f)] - [y_{C_2H_4}(t)])}{100 (W)(f-t)} $$

where,

- $R_{C_2H_4}$ = endogenous ethylene production rate (ppm kg$^{-1}$ h$^{-1}$)
- $t$ = time (hour)
- $W$ = weight (kg)
- $y$ = volumetric concentration ethylene, % v/v
- $i$ = beginning
- $f$ = end

2.2. Respiration measurement ($O_2$ and CO$_2$)
Barangan banana one comb was put into a closed chamber. The measurement technique was
carried out continuously interrupted. Respiration rate measurement by this method was done
by weighing the banana sample, and then the banana was put into the chamber with the
condition tightly closed, where the edges of the cover were closed with paraffin [5].
Respiration rate was measured every 3 hours at 8 points in one day for 6 days. The chamber
valve was opened, then it was connected to Gas Chromatography (GC). After the
measurement, the air in the chamber was refreshed so that the composition of the air (CO$_2$
and O$_2$) in the chamber was the same as the atmospheric. Measurement was made in the
same manner at a later time. The value of the fruit respiration rate was calculated by equation
2.
\[ R = \frac{V}{W} \cdot x_{dt}^{dx} \]  
(2)

where,

- \( R \) = respiration rate (\( \text{ml kg}^{-1} \text{h}^{-1} \))
- \( V \) = respiration free volume (ml)
- \( W \) = weight (kg)
- \( dx \) = change in concentration \( \text{CO}_2 \) or \( \text{O}_2 \) (%)
- \( dt \) = change in time (hour)

2.3. Color measurement (\( L^* \) and \( ^{\circ}\)hue)

Banana skin color was analyzed in 3 position points for color values, \( L^* \) and \( ^{\circ}\)hue. Color measurement using the Chromameter Minolta CR-300. This tool has 3 parameters of the Hunter color notation system, namely \( L^* \), \( a^* \), and \( b^* \). The measurement results in units \( a^* \) and \( b^* \) are converted in chromatic \( ^{\circ}\)hue units (figure 1).

![Figure 1. Chromatic \(^{\circ}\)hue color diagram](image)

Chromatic \(^{\circ}\)hue value indicated the dominant color in a combination of several observed colors. \(^{\circ}\)Hue value can be found by the following equation (equation 3).

\[ \text{Hue} = \tan^{-1} \frac{b}{a}, \]  
(3)

where,

- \( a \) = red (positive), green (negative)
- \( b \) = yellow (positive), blue (negative)

3. Result and discussion

3.1. Ethylene production and respiration rate

Ethylene production increases in climacteric fruit, whereas non-climacteric fruit does not change significantly. Ethylene concentrations above 0.1 ul can affect the shelf life of fruit, especially in climacteric fruit [6]. The rate of ethylene production is influenced by differences in the phases of the fruit harvest, which has an impact on ripening time during storage. Observation data on harvest time differences (figure 2), a peak of ethylene production \( P_{12} \), is earlier than the other at the 54 hours, i.e., 29.07 ppm kg\(^{-1}\) hour\(^{-1}\). Then, \( P_{11} \) gets a peak at 63 hours, i.e., 36.21 ppm kg\(^{-1}\) hour\(^{-1}\). The level of maturity forms different fruit cell structures, whereas a higher level of maturity gets a short period for ethylene production. In contrast to the treatment, \( P_{10} \) gets a peak of ethylene production at 69 hours, i.e., 34.80 ppm kg\(^{-1}\) hour\(^{-1}\). As for the total ethylene production for each harvest phase of \( P_{10}, P_{11} \) and \( P_{12} \), respectively 239.581, 287.195, and 270.712 ppm kg\(^{-1}\) hour\(^{-1}\). This data can be used as a basic reference for postharvest handling of Barangan bananas related to the addition of ethylene oxidizing agents.
Figure 2. Production of banana ethylene based on differences in harvest time

Data on ethylene production from harvest time differences do not provide enough information on the physiological characteristics of fruit maturity. Then the respiration rate information (O2 and CO2) will provide further study to see the relationship between ethylene production and respiration rate of Barangan bananas. In [7], ethylene can trigger fruit respiration rates. It overhauls the physico-chemical content to occur more quickly.

Respiration is an activity in fruit tissue related to O2 and CO2. It becomes an indicator of metabolic activity. Fruit respiration rates can be known by measuring the level of O2 consumption and CO2 respiration. Concentrations of O2 and CO2 in fruit become an important role in ethylene biosynthesis. In climacteric fruits, the peak respiration occurs due to accelerated maturation. It is stimulated by endogenous ethylene. Based on figure 2, the peak production of ethylene production (P10; P11; and P12) occurred on the 3rd day postharvest. Related with observations of respiration (RR O2) (figure 3) obtained P10 results of 17.84 ml kg\(^{-1}\) h\(^{-1}\). It gets peak respiration on the 3rd day. Respiration rate (RR O2) at P11 was 25.04 ml kg\(^{-1}\) h\(^{-1}\) with peak respiration on the 4th day. The P10 and P11 samples did not change significantly on the following day. However, the pattern shows that P10 and P11 get peak respiration of O2 after the peak of endogenous ethylene production. The respiration rate (RR O2) at P12 of 104.40 ml kg\(^{-1}\) h\(^{-1}\) gets a peak of respiration on the 4th day. P12 has a significant rate of change from day 3 to day 4, and then it has decreased. The maturity level of the fruit at harvest will determine the composition and structure of the cell, where the mature cells are more ready to respond and overhaul the cell components. So, the sample P12 has a significant rate of change postharvest.

Figure 3. Respiration rate (O2) of Barangan banana at harvest time differences
The rate of O\textsuperscript{2} consumption is directly proportional to the respiration of CO\textsubscript{2} produced in the metabolic process. Figure 4 shows the peak respiration rate of CO\textsubscript{2} along with the peak respiration rate of O\textsubscript{2}. Observation of respiration rates P12 also has a significant change compared to respiration rates P10 and P11.

![Figure 4. Respiration rate (CO\textsubscript{2}) of Barangan banana at harvest time differences](image)

3.2. Discoloration of fruit surface (L and \textsuperscript{°}hue)

The color parameter is one indicator of the maturity of Barangan bananas because this type of banana changes color very quickly. The most important compounds responsible for skin discoloration are chlorophyll and carotenoids [8]. Here is figure 5, the color change of L\textsuperscript{*} value of Barangan bananas at different harvest ages.

![Figure 5. Color change L\textsuperscript{*} value of Barangan banana peel during storage](image)

Figure 6 shows the color value of L\textsuperscript{*}, i.e., the brightness of P10, P11, and P12. The L\textsuperscript{*} values for P11 and P12 get a peak on the 6th day. Changes in P11 and P12 do not differ significantly from day 0 to day 15 during storage. The L\textsuperscript{*} values of P11 and P12 continued to increase, but only lasted until the 6th day, afterwords the L\textsuperscript{*} values are degraded. It was reported that increasing the value of L \textsuperscript{*}, a \textsuperscript{*}, and b \textsuperscript{*} is part of the development of maturity due to the chlorophyll degradation process [9]. In the study [10], observed the maturation pattern of Cavendish bananas without the addition of chemical agents with the peak L\textsuperscript{*} value on the 6th day, after that the L \textsuperscript{*} value was degraded. A decrease in L\textsuperscript{*} value is followed by the emergence of brown spots. It is spread on the surface of a banana peel. In contrast to P10, where P10 is the youngest crop showing slow L\textsuperscript{*} value changes during storage. The L\textsuperscript{*} value does not indicate degradation for 15 days of storage. The effect of fruit maturity on younger
harvest ages indicates a longer shelf life by a color indicator as a reference. The following table 1 shows changes in the value of $L^*$ per day.

**Table 1. Changes in the $L^*$ value of Barangan banana peels during storage**

| Harvest time | Day-0     | Day-3     | Day-6     | Day-9     | Day-12    | Day-15    |
|--------------|-----------|-----------|-----------|-----------|-----------|-----------|
| P10          | 47.40±1.62a | 49.19±1.94a | 50.51±3.96a | 53.33±6.11a | 63.21±4.23b | 66.18±2.31b |
| P11          | 50.84±0.69a | 50.79±1.02a | 65.61±1.75a | 58.19±7.50a | 33.48±1.68a | 29.96±5.75a |
| P12          | 51.46±3.70a | 60.18±10.85a | 64.60±1.05a | 58.44±4.42a | 37.30±4.33a | 33.50±4.48a |

*The figures in the column are followed by the same latter, showing no significant difference based on the DMRT level of 5%*

The value of $\theta$hue indicates the dominant color in a combination of several colors observed on the surface of the fruit skin. It is reported that the $\theta$hue values (figure 6) of samples P10, P11, P12 generally get a change from green-yellow-dark. The $\theta$hue value change for P12 is significant after the 12th day. A decrease in the $\theta$hue value in the diagram goes to the yellow-brown direction. This indicates a decrease in quality after maturation due to chlorophyll degradation [9,10]. However, it is difficult to judge the maturation stage and internal quality of the fruit based on the discoloration. Fruit skin color is only a physical indicator of the physiological processes that occur in cells.

![Figure 6](image)

**Figure 6.** Discoloration ($\theta$hue) of Barangan banana peel during storage

The positions of the colors for each sample P10, P11, and P12 in the $\theta$hue diagram are shown in figure 7. The area of each area swept between the green-yellow lines, then at the end of the observation approaching the color brown. The degree ($\theta$) hue can be more fully presented in table 2.

![Figure 7](image)

**Figure 7.** Ranges color position for (a) sample P10, (b) sample P11, and (c) sample P12
The changes in firmness of Barangan banana can be observed in Figure 8 below. Musa acuminata, which showed the greatest decrease in turgor rate 4-5 days after storage. Similar results are also obtained [13,14] related to the level of firmness of bananas decreasing tissue. The biggest decrease in turgor rate for P10, P11, and P12 are on the 6th day. This is due to the level of readiness of the tissue in the fruit, where the older age of harvest is faster in storage. P12 has a significant reduction rate at the beginning of storage. This is due to the fruit ripening process. P10, P11, and P12 have firmness values overall decreased during storage. Based on Figure 8, the decreasing of firmness value after harvest occurs at the stage of the harvest time.

Table 2. Changes in °hue value of Barangan banana peels during storage

| Harvest time | Day-0 | Day-3 | Day-6 | Day-9 | Day-12 | Day-15 |
|--------------|-------|-------|-------|-------|--------|--------|
| P10          | 120.04±0.55a | 126.48±11.54a | 120.80±13.15a | 105.93±16.87a | 88.61±13.75b | 79.62±1.42b |
| P11          | 118.35±1.14a | 120±7.70a | 126.88±12.04a | 101.17±4.75a | 76.83±11.43ab | 80.67±10.72b |
| P12          | 119.56±1.37a | 134.31±9.06a | 129.76±28.80a | 87.93±6.46a | 60.43±4.70a | 64.26±3.77a |

*aThe figures in the column are followed by the same letter, showing no significant difference based on the DMRT level of 5%.

3.3. Firmness of Barangan banana

The change of firmness in fruit is one of the physiological properties that occur due to the process of overhauling complex compounds from structural carbohydrate groups, such as cellulose, hemicellulose, pectin, and lignin [11]. Pectin also plays a role in building the strength of cells is broken down into sugars with the help of certain enzymes. The overhauling of pectin causes fruits to feel soft due to the decrement of firmness in fruit [12]. The changes firmness in the results of the research can be seen in figure 8 below.

Figure 8. The changes of firmness in Barangan banana during storage

Based on figure 8, the decreasing of firmness value after harvest occurs at the stage of the fruit ripening process. P10, P11, and P12 have firmness values overall decreased during storage. P12 has a significant reduction rate at the beginning of storage. This is due to the level of readiness of the tissue in the fruit, where the older age of harvest is faster in decreasing tissue. The biggest decrease in turgor rate for P10, P11, and P12 are on the 6th day. Similar results are also obtained [13,14] related to the level of firmness of bananas (Musa acuminata), which get the greatest decrease in turgor rate 4-5 days after storage. Barangan bananas without the addition of chemical agents can only last no more than 15 days of storage, after which they decay. The reduction data are presented in table 3 below.

Table 3. The changes firmness value of Barangan banana flesh

| Harvest time | Day-0 | Day-3 | Day-6 | Day-9 | Day-12 | Day-15 |
|--------------|-------|-------|-------|-------|--------|--------|
| P10          | 6.15±0.55b | 5.36±0.42b | 4.89±0.43b | 2.38±0.31b | 1.89±0.02a | 0.49±0.09a |
| P11          | 7.79±0.26c | 7.52±0.27c | 7.07±0.15c | 3.60±0.55c | 1.62±0.88a | 0.62±0.23a |
| P12          | 4.20±0.64a | 2.07±0.27a | 1.74±0.47a | 1.69±0.21a | 1.71±0.36a | 0.35±0.05a |

*aThe figures in the column are followed by the same letter, showing no significant difference based on the DMRT level of 5%.

3.4. Changes of total soluble solids

Fruits, including bananas, contain many components that are dissolved in water, such as sugar, acids, vitamin C, amino acids, and pectin. In most of the fruit in the ripening process,
sugar will form. It is produced from the hydrolysis of starch. Research [15] reported that the total soluble solids in bananas significantly increased during the ripening process as part of fruit maturity. Changes in total soluble solids per day are presented in figure 9 below.

**Figure 9.** The changes of total soluble solids in Barangan banana during storage

In this study (figure 10) obtained a different peak total soluble solids value, where P12 is faster sugar formation than the other. It produces 30.08 °Brix on the 6th day. Whereas P10 and P11, a peak of total soluble solids is formed on the 12th day, respectively 30.31 °Brix and 31.27 °Brix. In the study [13] obtained a peak formed total soluble solids on the 9th day of 23.41 °Brix. Researchers [15] reported that the banana "IDN110" showed the highest and maximum total soluble solids values at 23.26 °Brix. The difference in peak total soluble solids values is influenced by the harvest time of fruit. Data changes per day are presented in the following table 4.

**Table 4.** The changes of total soluble solids in Barangan banana

| Harvest time | Day-0   | Day-3   | Day-6   | Day-9   | Day-12  | Day-15  |
|--------------|---------|---------|---------|---------|---------|---------|
| P10          | 1.56±0.20ab | 3.80±0.45a  | 9.15±3.64a   | 20.83±3.52a | 30.31±0.71a | 25.48±1.41a |
| P11          | 2.06±0.40b  | 10.76±1.02b | 14.53±1.85a  | 25.14±2.47ab | 31.27±9.46a | 26.10±4.96a |
| P12          | 1.06±0.15a  | 20.59±1.52c | 30.08±4.40b  | 28.96±3.15b  | 26.52±1.01a | 27.55±0.80a |

*The figures in the column are followed by the same latter, showing no significant difference based on the DMRT level of 5%*

**4. Conclusion**

The P12 sample stimulated by ethylene earlier gets changes in the respiration rate faster than other samples. Brightness levels (L*) for P11 and P12 get a peak on the 6th day, while that for the P10 sample continues to increase until the 15th day. The hue (°) value for P12 undergoes the fastest yellow change, then approaches blackish color after day 12. Whereas P10 and P11 turn yellow later than P12, but it still maintains yellow until the 15th day. For the level of firmness, all samples get a decrease in the level of firmness until the 15th day. Total soluble solids at P12 gets a change in peak on the 6th day, while P10 and P11 experienced a peak on the 12th day. The optimum storage time for P12 is 6 days, while P10 and P11 are 12 days after harvest.

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