Theoretical calculation and experimental validation of ammonium molybdate concentration for fruit ripeness indicator label

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Abstract. It is indicated from the previous research that indicator label of fruits ripeness made from ammonium molybdate does not change color according to fruit maturity. The color change in the ripeness indicator label is due to the reaction between ethylene gas (C₂H₄) emitted from fruits and ammonium molybdate [(NH₄)₆Mo₇O₂₄·4H₂O] added into the label. The reaction produces molybdenum blue that turns the color of ammonium molybdate from yellow to blue. This research is approached based on the theoretical calculation of the requirement of ammonium molybdate as a change color in the label and then it is validated in the laboratory. Theoretical calculations of ammonium molybdate reaction with ethylene gas are based on stoichiometry. The result shows that 1 gram of ammonium molybdate reacts with 0.136 gram ethylene gas. The oxidation number of Mo decreased from Mo(VI) in the form of [Mo₈O₂₆]⁴⁻ to Mo(V) in the form of [Mo₈O₂₂(H₂O)₂]⁴⁺. The experimental validation in this study is carried out by exposing the label containing ammonium molybdate with ethylene gas into tightly closed jar. At the beginning of the storage, the label was yellow but at the end of the storage, the label color changed to reddish brown either for the sample exposed with ethylene or without ethylene. This research is continued by increasing the RH of the jar to 85% and the result shows that the label turned green at the end of storage. The performance of the label as ripeness indicator is also tested by sticking label in the jar where 1 kg of banana had been previously stored. The label indicates change in color from yellow to dark blue thus it is concluded that the label resulted from this research is potential to be used as ripeness indicator for fruits.

1. Introduction

Theoretical calculations can be done on the application of the fruit ripeness indicator label. Fruit maturity indicator labels are labels that are placed or put in packages to monitor product quality [1] [2] [3] [4] [5]. In the research [6], it was mentioned that apples can be known for their level of maturity with an indicator label made from ammonium molybdate [(NH₄)₆Mo₇O₂₄·4H₂O]. This label can change color after reacting with ethylene released by those apples. Ethylene is a plant hormone in the form of gas and plays an active role in the maturation process [7]. The indicator label changes color from yellow to blue on the indicator label due to the reduction in Mo (VI) to Mo (V) when reacting with the ethylene gas emitting from the fruits [8].

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Research on the label indicator made from ammonium molybdate has also been done before, but it still has shortcomings including the fact that indicator color label made from ammonium molybdate does not change color when exposed to gas ethylene [9] because the capability of matrix to absorb the ethylene gas was too low. Subsequently, a research on smart label to detect fruit ripeness using PVA (polyvinyl alcohol) as a form of matrix has resulted a bubbly surface, [10] thus an improvement has been done [11] by storing ammonium molybdate solution in the temperature of 7°C for a week.

However, in all previous research studies, there was something missing in the theoretical calculation about the amount of ammonium molybdate needed for the indicator label/matrix in order to react completely with ethylene gas so that the color of the label can change. In other words, it needs appropriate amount of ammonium molybdate in accordance to the amount of ethylene gas released from the fruit thus the redox reaction between them occurs properly and a color change of the label appears. Based on this summary, a research still needs to be done to find out the amount of ammonium molybdate needed at certain ethylene gas concentrations based on known chemical of the stoichiometry. It is expected that the use of the exact ammonium molybdate as a ripeness indicator label can be measured and it does not lack or excess thus the indicator label changes color according to the amount of ethylene gas released from the fruit.

2. Materials and methods

2.1 Materials and equipment

The materials used in this study included ammonium molybdate [(NH₄)₆Mo₇O₂⁴·4H₂O], hydrogen peroxide (H₂O₂) solution, H₂SO₄ solution, PVA (polyvinyl alcohol), glycerol, distilled water and ethylene gas. Equipment used were portable colorimeter, glass chamber, gas tight syringe, pH meter, RH meter and drying oven.

2.2 Methods

2.2.1 Theoretical calculations of ammonium molybdate requirement. The reaction equation for the theoretical calculation of the requirement for ammonium molybdate is as follow [6]:

\[
\begin{align*}
[\text{Mo}_7\text{O}_{24}]^{2+} + 4\text{H}_2\text{O}_2 & \rightarrow [\text{Mo}_6\text{O}_{24}(\text{O}_2)(\text{H}_2\text{O})_2]^{2+} + 2\text{H}_2\text{O} \\
2\text{C}_2\text{H}_4 + [\text{Mo}_6\text{O}_{24}(\text{O}_2)(\text{H}_2\text{O})_2]^{2+} & \rightarrow 2\text{C}_2\text{H}_4\text{O} + [\text{Mo}_6\text{O}_{24}(\text{H}_2\text{O})_2]^{2+} \\
\text{C}_2\text{H}_4 + [\text{Mo}_6\text{O}_{24}(\text{H}_2\text{O})_2]^{2+} & \rightarrow \text{C}_2\text{H}_4\text{O} + [\text{Mo}_6\text{O}_{24}(\text{H}_2\text{O})_2]^{2+}
\end{align*}
\]

This calculation was done by stoichiometry which was based on the basic laws of chemistry, namely the law of conservation of mass, the law of fixed comparison, and the law of multiple comparisons.

2.2.2 Experimental validation of ammonium molybdate indicator labels

2.2.2.1 Solution preparation of color indicator. Ammonium molybdate solution as color indicator was made by referring the calculation from 2.2.1. This compound of ammonium molybdate [(NH₄)₆Mo₇O₂⁴·4H₂O] was dissolved in 35% H₂O₂, then homogenized with a magnetic stirrer until it completely dissolved. Further, the solution was added with a 20% H₂SO₄ solution until it reached pH of 1.5 and it was mixed until the solution turned yellow. The solution was then stored in a refrigerator at 7-10°C for 3 days [10].

2.2.2.2 Manufacturing of indicator label. The label in this study was made from PVA (polyvinyl alcohol) films. As much as 3.5 grams of PVA was homogenized in 100 mL of distilled water at 70-80°C, then 2 mL of glycerol was added and stirred until it dissolved completely. Ammonium molybdate color solution was then added into PVA solution with 4% v/v concentration. The mixed
solution was placed on a glass plate and dried with a drying oven for 18 hours at 40°C to form film.

2.2.2.3 Label sensitivity test to ethylene gas and humidity. Label sensitivity test was carried out to see the sensitivity of the label to ethylene gas and humidity. Testing was done by placing labels on the walls of a tightly closed glass container. At this stage, the container was injected with ethylene gas and RH of the container was adjusted. Containers were prepared and injected with ethylene gas of 5,000 ppm and 10,000 ppm with 70% RH. A container without ethylene gas was also prepared as a control in the RH of 70%. Other treatments were containers with 10,000 ppm ethylene gas in 85% RH and a control (container without ethylene gas in 85% RH). RH adjustment was done by placing a paper in the size of 10 cm × 10 cm at the bottom of the container, which had previously been soaked in water for one hour. During storage, color change of the label was observed. The color change was measured quantitatively using a portable colorimeter. Values obtained from measurements were L, a, b, chroma, and °hue values.

2.2.2.4 Application of label indicator as a detection of fruit ripeness. Application of the label on the fruit especially bananas, was aimed to determine the relationship of the maturity of bananas with the change color of the label. This test was done by placing 1 kg of bananas into a glass container with a volume of 3,100 mL, then the container was tightly sealed. Indicator labels were previously placed on the glass wall with tape. Samples were stored at room temperature (30 ± 1 °C) until the fruit had overripe or the label did not change color anymore or the color was constant. Observations were made on changes in the color of the indicator label and the color of banana skin, and RH containers during storage were observed with RH meters.

3. Result and discussion

3.1 Theoretical calculations of ammonium molybdate requirement

Theoretical calculation of the ammonium molybdate needed for reaction was done so that the addition of ammonium molybdate to the indicator label can be proper in accordance with the presence of ethylene gas concentration emitted from the fruit so that the ammonium molybdate-based indicator label can change color according to the level of fruit ripeness. The indicator label of ammonium molybdate can change color from yellow to blue due to the redox reaction between molybdenum and ethylene gas. Ethylene gas (C₂H₄) undergoes oxidation to C₂H₂O and molybdenum is reduced from Mo (VI) to Mo (V) [8] as in equation (1), (2) and (3). In equation (1), reaction is the formation of peroxymolybdate, by mixing molybdate anion in peroxy hydroxide (H₂O₂). Then peroxymolybdate decomposes when it reacts with ethylene gas according to equation (2). Then the reaction is followed by a reduction in Mo (VI) with ethylene gas so that it produces a blue color according to equation (3).

In the chemical reaction equation above, the end result of Mo after reacting with ethylene gas in [Mo₈O₂₆(H₂O)₂]⁺ had an oxidation number of 5.75. So that further reactions were carried out until the oxidation number of Mo becomes 5 so that the theoretical calculations obtained were in accordance with the change in color of ammonium molybdate and O₂ was produced by presence of bubbles in the solution when ammonium molybdate was dissolved into peroxy hydroxide (H₂O₂), thus equation (1) and (2) can be modified as equations (4) and (5).

\[
[\text{Mo}_8\text{O}_{26}]^{+} + 4\text{H}_2\text{O}_2 \rightarrow [\text{Mo}_{6}\text{O}_{24}(\text{O}_2)_{2}]^{+} + 2\text{H}_2\text{O} + \text{O}_2 \tag{4}
\]

\[
6\text{C}_2\text{H}_4 + [\text{Mo}_8\text{O}_{26}(\text{O}_2)_{2}(\text{H}_2\text{O})_{2}]^{+} \rightarrow 6\text{C}_2\text{H}_2\text{O} + [\text{Mo}_6\text{O}_{22}(\text{H}_2\text{O})_{2}]^{+} \tag{5}
\]

In this study, the ammonium molybdate had a chemical formula of [(NH₄)₆Mo₇O₂₄·4H₂O]. Meanwhile, in equation (4), the reactants added with H₂O₂ were [Mo₈O₂₆]⁺, so that an additional chemical equation was needed to calculate the amount of ammonium molybdate in accordance to the reaction. The ammonium molybdate [(NH₄)₆Mo₇O₂₄·4H₂O] could be converted in the form of hydrates containing heptamolybdate ions (Mo₇O₂₄⁶⁺). The reaction can be seen in equation (6) [12].

\[
\text{(NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O} + \text{H}_2\text{O}_2 \rightarrow (\text{NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O} + \text{H}_2\text{O}_{26}\text{O}^{+} + \text{H}_2\text{O} \tag{6}
\]
Heptamolybdate (Mo$_{7}$O$_{24}$$^{6-}$) ions can decompose in acidic solutions that have pH <2 and it will produce [MoO$_4$]$^{2-}$, [Mo$_8$O$_{26}$$^{4-}$], [Mo$_{36}$O$_{112}$(H$_2$O)$_{16}$$^{8-}$] [6]. The equation for the pH reduction in reaction of (Mo$_{7}$O$_{24}$$^{6-}$) can be seen in equation (7) [13].

Mo$_{7}$O$_{24}$$^{6-}$ + 3H$^+$ → Mo$_8$O$_{26}$$^{4-}$ + 2H$_2$O

(7)

Based on the above reaction equations, the basis for carrying out theoretical calculations of molybdate requirements was obtained. The calculation starts from the reaction equation when peroximolibdat reacts with ethylene gas (equation 4). The stoichiometric reaction of the requirement for ammonium molybdate can be seen in Table 1.

### Table 1. Stoichiometric reactions for ammonium molybdate requirement.

| Reactant | Product |
|----------|---------|
| 6C$_2$H$_4$ + [Mo$_8$O$_{26}$(O$_2$)$_2$(H$_2$O)$_2$]$^{4+}$ → 6C$_2$H$_4$O + [Mo$_8$O$_{26}$(H$_2$O)$_2$]$^{4+}$ | |
| Initial reaction | Reaction |
| 6 mol | 6 mol |
| 1 mol | 1 mol |
| Excess | |
| 0 | 6 mol |
| 0 | 1 mol |
| 1 mol | 2 mol |
| 4 mol | 1 mol |

| [Mo$_7$O$_{24}$$^{6-}$] + 3H$^+$ → [Mo$_8$O$_{26}$$^{4-}$] + 2H$_2$O + O$_2$ | |
| Initial reaction | Reaction |
| 1 mol | 1 mol |
| 4 mol | 4 mol |
| Excess | |
| 0 | 1 mol |
| 0 | 2 mol |
| 1 mol | 1 mol |
| 1 mol | 1 mol |

| [NH$_4$)$_6$Mo$_7$O$_{24}$4H$_2$O] → [Mo$_7$O$_{24}$$^{6-}$] + (NH$_4$)$_+$ + 4H$_2$O | |
| Initial reaction | Reaction |
| 1 mol | 1 mol |
| 1 mol | 1 mol |
| Excess | |
| 0 | 1 mol |
| 0 | 1 mol |
| 1 mol | 4 mol |

The calculation basis used was 1 mole, so that it was found that 6 moles of ethylene gas (C$_2$H$_4$) could reacted with 1 mole of ammonium molybdate ([NH$_4$)$_6$Mo$_7$O$_{24}$4H$_2$O]), or by units of weight, it means that 1 gram of ammonium molybdate would react with 0.136 grams of ethylene gas. In the manufacture of ammonium molybdate solution with hydrogen peroxide, 1 mole of ammonium molybdate could react with 4 moles of hydrogen peroxide, it is therefore based on these calculations, 1 gram of ammonium molybdate could react completely with 0.06 mL of 35% hydrogen peroxide.

### 3.2 Calculation of ethylene gas for injection

Calculation of ethylene gas was necessary to determine the volume of the gas that would be injected in a closed glass container. This calculation was based on the following formula:

\[ C_1 \times V_1 = C_2 \times V_2 \]  

(8)
Where $C_1$ was the concentration of ethylene gas from the tank, $V_1$ is the volume of ethylene gas to be injected in a glass container, $C_2$ is the desired concentration of ethylene gas in glass container, and $V_2$ is the volume of the glass container.

The glass container used had a volume of 3,100 mL. The concentration of ethylene gas in a glass container was set 10,000 ppm. The concentration of ethylene gas was 100% or 1,000,000 ppm. So that the calculation of the ethylene gas injection volume (10,000 ppm) was as follows:

$$C_1 \times V_1 = C_2 \times V_2$$  \hspace{1cm} (9)

$$1,000,000 \text{ ppm} \times V_1 = 10,000 \text{ ppm} \times 3,100 \text{ mL}$$  \hspace{1cm} (10)

$$V_1 = 31 \text{ mL}$$  \hspace{1cm} (11)

After the ethylene gas injection volume was obtained, the volume of ethylene gas was converted in units of grams in order to obtain the mass of ammonium molybdate in accordance with previous calculations. The density of ethylene gas at a pressure of 1 atm and a temperature of 30°C was 1.135 kg/m$^3$ [14]. Thus, the mass of ethylene gas obtained was 0.03514 grams to react with 258 mg of ammonium molybdate.

### 3.3 Experimental validation of ammonium molybdate indicator labels

#### 3.3.1 Manufacturing of Color Indicator Solution. The color of indicator solution was made by dissolving ammonium molybdate [(NH$_4$)$_6$Mo$_7$O$_{24}$·4H$_2$O] in H$_2$O$_2$ solution [4] [9] [10] [11]. In the calculations carried out in the previous method, 1 mole of ammonium molybdate would react with 4 moles of H$_2$O$_2$. Thus, 285 grams of ammonium molybdate could react with 0.06 mL of 35% H$_2$O$_2$. In its application in the laboratory, the amount of H$_2$O$_2$ solvent was too small and the color solution was very bubbly. Thus, in this study 258 grams of ammonium molybdate was dissolved in 2.58 mL of hydroden peroxide based on the research [9] that the best concentration of ammonium molybdate and hydrogen peroxide was 10% w/v. In this research, the addition of H$_2$SO$_4$ solution to the color indicator solution was done because of the heptamolibdate ion (Mo$_7$O$_{24}^{-6}$) will become Mo$_8$O$_{26}^{4-}$ ion in acidic solutions with pH <2 [2]. The color indicator solution was stored in a refrigerator at 7-10°C for 3 days. Storage of the color indicator solution in the cool room could reduce the formation of bubbles which causes the appearance of labels to be unattractive [11].

#### 3.3.2 Manufacturing of label indicator. The indicator label was made from PVA (polyvinyl alcohol). The concentration of the addition of the color indicator solution in the PVA solution was 4% v/v [10], so that the 2.58 mL color indicator solution was dissolved in 64.5 mL of the PVA solution. In this study, the PVA solution which had been added to the color indicator solution was dried by drying oven at 40°C for 18 hours [11]. This drying resulted in a yellow PVA label with smooth and no-bubbles appearance. Color measurement with a colorimeter produced L value of 66.38, a value was -2.44, b value was 15.79, chroma value was 15.98, and °hue value was 98.66.

#### 3.3.3 Sensitivity test of indicator labels on ethylene gas. This test aims to determine the sensitivity of the label to the presence of ethylene gas. The sensitivity of the indicator label was indicated by changes in the color of the label. In previous study, the indicator label was tested with an ethylene gas concentration of 250 ppm and 500 ppm and experienced a change in color from yellow to green [10]. The indicator labels with ammonium molybdate, palladium sulfate (PdSO$_4$), and hydrogen peroxide change color from yellow to blue [6].

In this study, the indicator label was exposed in the closed jar containing ethylene gas with a concentration of 5,000 and 10,000 ppm at 70% RH and jar without ethylene gas as control at 70% RH. The change in the color of the indicator label was observed with a colorimeter. Color measurements would produce values of L, a, b, chroma and °hue. Value of °hue with angles ranging from 0° to 360°.
was divided into 4 quadrants [15]. Hue and chroma were values that represent the actual color visually, and they were obtained from the conversion of values a and b. Chroma value is the color density that can be used to see the color saturation [16]. The hue value chart and the chroma label indicator diagram for the control treatment and the various ethylene gas concentration treatments can be seen in Figures 1, 2 and 3.

Figure 1. Graph of hue values and chroma diagram of label in the control with 70% RH (● beginning of storage and ● end of storage).

Figure 2. Graph of hue values and chroma diagram in 5,000 ppm ethylene with 70% RH (● beginning of storage and ● end of storage).
Based on the graphs in Figures 1, 2, and 3, it is known that the color of the initial storage indicator label is in quadrant 2, which is between the yellow-green color. Visually the label has a bright yellow color. At the treatments of 70% RH without ethylene gas (control treatment), the °hue value of the label decreases to 49.4 in 217 hours. The °hue value at the end of the storage in this control is in quadrant 1 which is the color between red-orange-yellow. In the ethylene treatment of 5,000 and 10,000 ppm at 70% RH, the label initially decreases its °hue value until the 160th hour, but at the end of storage the °hue value increases to above 300. The change of color of the label on the ethylene treatment of 10,000 ppm is faster than 5,000 ppm one and reaches the °hue value above 300 after 165 hours of storage compared to the label with 5,000 ppm which reaches the similar value after 189 hours of storage. These labels exposed in container containing the ethylene gas has shown the final °hue value in quadrant 4, or the color of the label is in between red-purple-blue. The color change of label on the ethylene treatment of 5,000 and 10,000 ppm at 70% RH has the same pattern, this shows that the oxidation number of molybdenum on label is quicker than reduction by the presence of ethylene. Visually, the color of the label underwent the same final color change in all treatments, reddish-brown.

3.3.4 Sensitivity test of indicator labels various humidity. This test was carried out because in the previous ethylene gas test, the label did not turn to blue and the label experienced the same color change on all treatments at the end of storage. This test was carried out to determine the label's sensitivity to moisture in the container. In the previous research it was mentioned that the temperature and the humidity also had an influence on label color changes [4][6]. In this sensitivity to moisture-test, the label was given two treatments. The first treatment was the label placed into closed gas container without ethylene gas with 85% RH as a control and the second treatment was injecting container with 10,000 ppm ethylene with 85% RH. The °hue value graph and chroma diagram label for the presence of water vapor can be seen in Figure 4 and Figure 5.

Based on the graphs in Figures 4 and 5, it is known that at the beginning of storage the two indicator labels have a °hue value of around 95 which is in quadrant 2. At the 85% RH control treatment and 10,000 ppm ethylene treatment 85% RH, it has a similar color change in the label which were °hue values of 87.48 and 88.22 at the end of storage. This result is different from the statement that the change in label color will increase along with the increase of ethylene concentration [4][11]. Both label treatments have the same color change, thus the label color is in quadrant 1 at the end of storage or it is in between red-orange-yellow. This result shows that in addition to ethylene gas, the
oxidation number of Mo on the label can also be reduced by increasing the RH of the container, therefore the color of the label could turned into green color.

![Graph of hue value and chroma diagram label in control 85% RH](image1)

**Figure 4.** Graph of hue value and chroma diagram label in control 85% RH (● beginning of storage and ● end of storage).

![Graph of hue value and chroma diagram label in 10,000 ppm ethylene 85% RH](image2)

**Figure 5.** Graph of hue values and chroma diagram label in 10,000 ppm ethylene 85% RH (● beginning of storage and ● end of storage).

3.3.5 Application of indicator labels to detect bananas ripeness. The fruit ripeness indicator label is used to determine the maturity level of bananas. This label is used to provide information about the level of ripeness of bananas during storage. In this test, 1 kg of bananas was placed in a closed glass container with a volume of 3,100 mL. The container was stored at room temperature (30 ± 1 °C) until the label turned blue. The bananas used in this study were banana matures from the tree and has not ripen yet. The chart of hue and chroma value of the label and banana skin diagram can be seen in Figure 6. The value of the measurement of the color change of the labels and the appearance of banana skin during storage can be seen in Table 2.

Based on Figure 6, it can be seen that the label at the beginning of storage is yellow, then the label starts to turn bluish at 52 hours until the label color turns to dark blue at the end of storage. At the beginning of storage the banana skin had a hue value of 109.7 or light green banana skin. The color of the banana skin continued to turn to yellow at the end of storage, the hue value of banana skin at the end of storage is 82.32. The label turns blue with a change in the color of the yellowing of a
banana skin with brown patches that indicate that the banana is ripe. The application of labels on RH bananas on average during storage is 91%. This indicates that with higher RH level in the container, the water vapor around the container could help the ethylene gas to reduce the oxidation number of molybdenum on the label so that the label color changed from yellow to blue. The color change in a mixture of ammonium molybdate can be influenced by humidity, temperature, and sunlight [17].

![Graph](image1)

(a) $\theta$ hue graph

(b) chroma diagram

**Figure 6.** Graph of $\theta$ hue values and chroma diagram of labels and banana skin (● beginning of storage and ● end of storage).

Based on Table 2, it is known that on the 0th day when the bananas were first stored, the indicator label was bright yellow and the skin of the banana was green. The color of the label and banana skin is in quadrant 2, it was yellow-green. The indicator label starts to get bluish on 2nd day and the color of the banana skin starts to become yellow. On the 6th day, the storage of the label changed to dark blue and the color of the banana skin turned yellow and had a brown patch which indicates that the banana has already ripen. During storage, the banana skin color varies because these bananas used in this experiment are bananas without curing or previous treatment. According to [18], the ripeness of bananas has a varying level of maturity. When the ripening process is carried out at a temperature of 30 °C, the banana will become soft, but the skin color is still green or resulting in a ripe banana green [7] [18]. The label color on day of 6th is in quadrant 4 which is blue-purple-red while the color of banana skin is in quadrant 1, red-orange-yellow.

**Table 2.** Chroma and $\theta$ hue values of the label and banana skin during storage.
| Day | Label color values | Bananas skin color values | Appearances |
|-----|---------------------|---------------------------|-------------|
|     | chroma | hue   | chroma | hue   |                                      |
| 0   | 16.41  | 99.05 | 11.97  | 106.23 |
| 1   | 15.13  | 100.47| 15.10  | 108.69 |
| 2   | 8.11   | 110.52| 12.05  | 100.83 |
| 3   | 3.12   | 135.45| 12.69  | 97.62  |
| 6   | 0.51   | 327.84| 7.65   | 83.05  |

4. Conclusion
Based on research that has been done, it can be concluded that 1 mole of ammonium molybdate can react with 6 moles of ethylene gas, or as much as 1 gram of ammonium molybdate can react with 0.136 grams of ethylene gas. In experimental validation of the ammonium molybdate indicator label, the label in the control treatment and the label exposed in 5,000 ppm and 10,000 ppm ethylene gas show changes of color at the end of storage. Values of ϡhue label are 49.51, 310.40, and 354, 91 respectively. Visually, the label has the same color change, namely reddish brown color at the 217th hour. The label exposed in 10,000 ppm of ethylene gas at 85% RH and without ethylene has experienced a color change at the end of storage. Both labels experienced a reddish green color with ϡhue values of 88.22 and 87.45 at the 22nd hour. Labels applied to bananas in glass containers show a change of color as the bananas ripe proven by changes in the color of banana skin to yellow at the end of storage. The average RH in the glass container shows a value of 91% during storage. On day 0th to day 1st of banana storage, the label was still yellow with a ϡhue value of 99.05, the color of the label starts to turn bluish yellow on the second day with a ϡhue value of 110.52. The label changes color to dark blue at the end of storage with a ϡhue value of 327.84.

5. Reference
[1] Kerry J and Butler P 2008 Smart Packaging Technologies for Fast Moving Consumer Goods (England: John Wiley & Sons Ltd.)
[2] Nofrida R, Warsiki E and Yuliasih I 2013 Pengaruh suhu penyimpanan terhadap perubahan warna label cerdas indikator warna dari daun erpa (Aerva sanguinolenta) Jurnal Tin 23 232–
[3] Warsiki E and Rofifah N 2018 Dragon fruit freshness detector based on methyl red colour indicator *IOP Conf. Ser. Earth Environ. Sci.* **209** 012016

[4] Putri V J and Warsiki E 2019 Application nano zeolite-molybdate for avocado ripeness indicator *IOP Conf. Ser. Earth Environ. Sci.* **347** 012063

[5] Putri P G and Warsiki E 2019 The stability of extract *Indigofera tinctoria* for color indicator *IOP Conf. Ser. Earth Environ. Sci.* **347** 012070

[6] Lang C and Hubert T 2011 *Food Bioprocess Tech.* **5** 3244–3249

[7] Winarno F G 2002 *Horticultural Product Harvesting Physiology* (Bogor: M-BRIO Press)

[8] Kim J H and Shiratori S 2006 *J. Appl. Phys.* **45** 4274–4278

[9] Perangin-Angin A B 2017 Ethylene color indicator to detect climacteric fruit ripeness [Thesis] (Bogor: IPB University)

[10] Harmaji D D 2017 Label cerdas pendeteksi kematangan buah klimakterik berbahan PVA (polivinil alkohol) [Thesis] (Bogor: IPB University)

[11] Wibowo W S 2018 Perbaikan kinerja label indikator warna amonium molibdat sebagai pendeteksi kematangan buah klimaterik [Thesis] (Bogor: IPB University)

[12] Chiang T H and Yeh H C 2013 *Materials (Basel)* **6** 4609–4625

[13] Cotton F A, Wilkinson G, Murillo C A and Bochmann M 1999 *Advanced Inorganic Chemistry, 6th Edition* (New York: John Wiley & Sons Inc.)

[14] Engineering ToolBox 2018 *Ethylene-Density and Specific Weight* [Internet] Available at: https://www.engineeringtoolbox.com/ethylene-ethene-aceteneC2H4density-specific-weight-temperature-pressure-d_2105.html

[15] MacDougall D B 2002 *Colour in Food: Improving Quality* (Washington: CRC Press)

[16] Hariyanto D 2009 *Telkomnika* **7** 13–22

[17] Klein R, Riley N, DeCianne D and Srinavakul N 2018 Non-invasive colorimetric ripeness indicator (Patent: US20060127543A1)

[18] Cahyono B 2009 *Banana Farming and Its Post Harvest Handling* (Yogyakarta: Kanisius Publisher)