Study of Post-Harvest Ambon Banana (*Musa acuminata*) Preservation Using X-Ray

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Abstract. An exposure to Ambon banana (*Musa Acuminata*) samples has been done by using X-rays with current, voltage and exposure time are control parameters. This study aimed to determine storage ability of the post-harvest sample. Five samples were exposured by x-rays with the dose of (3-5)x 10^{-14} Gy. The samples were stored at room temperature. Their mass and physical condition (color and smell) were evaluated every 3 days. It was found that the control sample which was not exposured by X-ray was ripe in the sixth day indicated by the yellow color and good smell of the banana. Meanwhile, the samples which were exposured by (3 – 5)x 10^{-14} Gy doze of X-ray looked fresher and still had green color. These samples showed their ripening in the ninth day and their mass decrease was (12-13)% which is lower than the control sample. The preservation of banana can be done through low-dose X-ray exposure.

1. Introduction

Ambon banana (*Musa acuminate*) is one of the important groups of tropical fruits that is rich in sugar, grown in several countries, including Indonesia and favored by many people. This banana is classified as climacteric fruit in which its quality easily degenerates due to environmental factors. To be optimally consumed, preservation techniques are important and can be done either by using traditional method or ionizing radiation [1-2]. Gamma rays are one of the most frequently used ionizing radiation, as they have the nature of ionization when they pass through a material. In food preservation process, gamma rays (Co-60) have been used to kill microbes in chili powder [3].

Another kind of electromagnetic radiation which have ionizing properties is X-rays. X-rays are an electromagnetic radiation with a wavelength range between 100 eV to 100 keV resulted from the collision of electrons with a metal. The intensity of X-rays can be easily controlled by adjusting the accelerating voltage and current of the filaments [4]. X-rays have similar characteristics with gamma rays in terms of their penetration power and ionization properties which make them beneficial in food preservation process. In the preservation of bananas, Zhongli Pan found that heat exposure using infrared on banana can reduce water content which results in shrinkage of mass, increasing its crispness [5].

Bananas have distinctive characteristic where their metabolism persists despite being harvested. One of their properties is a respiratory metabolism which is a decomposition process of complex organic compounds into simpler dissolved compounds. The process of respiration produces ethylene

gas (ethene) as a by-product which is an unsaturated compound. The process of respiration occured after the fruit is harvested following the reaction of $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy. In such climacteric fruit as bananas, there is an increase in respiration rate and the levels of ethylene gas during the ripening process.

At the growth and development stages, the fruit visually shows physical changes. Discoloration on the fruit which appears is the loss of green color. The lost of green color in climacteric fruit occurs very quickly after entering the phase of ripening. Changes in natural dyes usually occur due to degradation or synthesis or both processes. The green color changes to yellow, red or orange due to the formation of carotenoids and breakdown of chlorophyll. The banana preservation contemplated in this study is to inhibit the process of fruit ripening by exposuring it to X-rays. This research is an initial study on ways to preserve bananas using a new alternative.

2. Experimental method

The samples of Ambon bananas were taken from Gunung Pati Semarang. There were five samples, each sample consisted of two bananas. Once they were washed and dried, the samples were then weighed with digital balance. The samples were exposed to the X-ray machine at the distance of 80 cm. The current was controlled at 32 mA with varying voltage of 50-90 kV within 2 seconds. After exposure process, the samples were stored at room temperature. They were evaluated every 3 days by measuring the mass of the bananas and their physical conditions (colors and smell of fruit) were observed. X-rays were generated from an SF 100 BY type of X-ray beam machine at Physics laboratory, Universitas Negeri Semarang, Indonesia. In this experiment, the bananas were placed on the table and a tool was used to control and regulate the sweep area as shown in Figure 1.

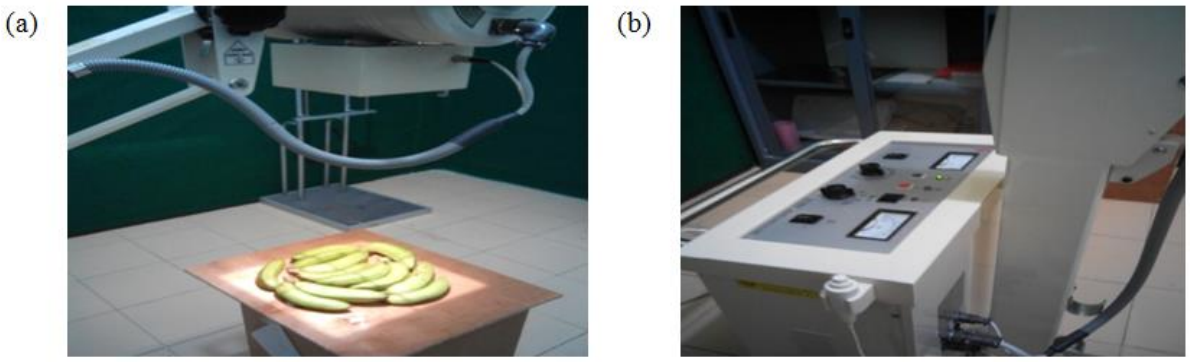

Figure 1**.** (a) The current and voltage control table. (b) Sweep area to place the samples

2.1. *Bananas mass shrinkage*

The mass of the samples exposured by X-rays and control sample (K) were weighed during the process of ripening. The weighing was done every 3 days using a balance and the mass was calculated by using equation [6]

$$\%\Delta m = \frac{m_{final} - m_{initial}}{m_{initial}} \times 100\%$$

3. Result and discussion

In the control banana (K), we observed ripening on the 6th day of measurement, indicated by its yellowish color and its good smell. Meanwhile, the banana samples that were exposed to X-rays with dose of (3-5)x10^{-14} Gy still looked fresh and did not show any ripening as shown in Figure 2a. These results showed that the X-ray exposure prevented the ripening process of the bananas in comparison to the control banana. The reason for this result can be explained as follows. In the bananas, there is always a process of cell reproduction which results in the ripening day by day. In this process,

ethylene gas is generated and its content will increase with time. This ethylene gas is indicated by the good smell of the bananas. With increasing time, the bananas loss their green color because of the structure degradation of the chlorophyll and the formation of carotene (yellow pigment turns into red). When the bananas are exposed by X-rays, the harvesting organ in the bananas will interact with X-rays. These X-rays will release electrons from the atomic bond of the molecules inside the bananas. This, in turn, leads to the breaking of chemical bonds of the molecules which damages DNA or RNA in the bananas. Because of the damage of DNA or RNA, the reproduction process becomes ineffective and cell division is suppressed which will hamper the ripening process [7].

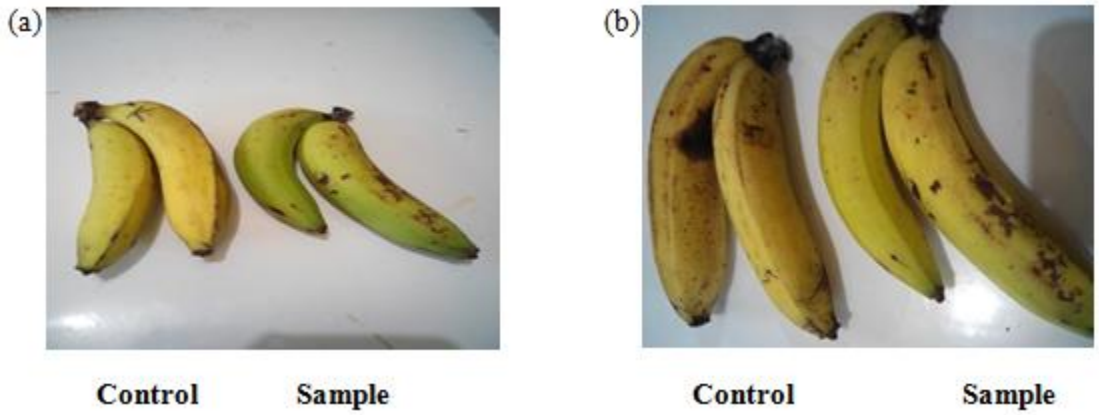

Figure 2. Irradiated control sample and tested samples after (a) 6 days and (b) 9 days.

On the 9th day of measurement, we observed further changes in the control banana. The good smell became stronger and a black-brownish stain was observed. Meanwhile, the samples which were exposed by X-rays began to ripe as indicated by its yellow color in Figure 2b. These results showed that the ripening process can be suppressed up to 9 days with the given X-ray dose.

Table 1. Mass shrinkage of Ambon banana (gram)

Sample	Absorbed Dose (Gy)	3 days	6 days	9 days	% m shrinkage
1	3×10^{-14}	13.99	22.78	31.51	12.5
2	3.7×10^{-14}	15	23	32	12
3	4×10^{-14}	17	25	34	13
4	4.7×10^{-14}	18	27	35	13
5	5×10^{-14}	17.2	25.85	33.78	12.31
Control (K)	0	19.65	29.68	40.68	14.7

Table 1 and Figure 3 show the shrinkage of the mass due to X-ray exposure. In the ripening process of bananas, the content of carbohydrate (starch) and sugar will always change. The content of starch will decrease during the ripening process which results in the shrinkage of the mass. This shrinkage is associated to the change of the starch into fructose and glucose. This change from starch to fructose and glucose will continue until no more starch available. Because of the increase of fructose and glucose content, the sugar content (sucrose) will also increase. In addition, bananas have cycles during the process of respiration, namely, a sharp increase in CO_2 when they reaches their ripening and then decreases when they ripe [8]. This CO_2 production will cause further mass shrinkage of the bananas.

As indicated in Table 1, during nine days of the ripening process, the X-rays with a dose of (3-5) $x10^{-14}$ Gy can cause shrinkage of the mass of bananas around 12-13% which is lower than the control samples. However, we found that the variation of the absorbed dose did not significantly influence the percentage of the mass shrinkage. After nine days of the measurement, we found that the samples were starting to ripe, but not perfectly ripe. Meanwhile the control sample has reached the maximum level of ripeness shown by its blackish brown spots on the fruit. It can be concluded that the X-rays with the given dose are able to inhibit the ripeness of the fruit, so the bananas irradiated by the X-rays are more durable.

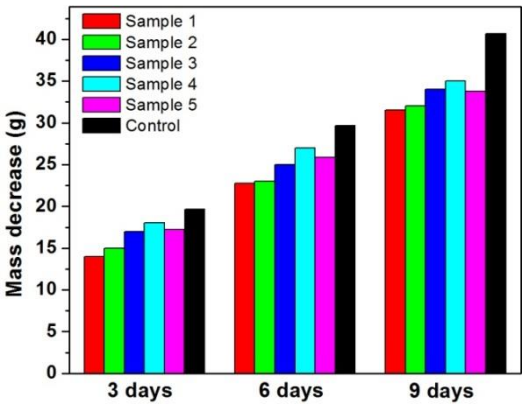

Figure 3. Graph of banana mass shrinkage.

4. Conclusion

The Ambon bananas which were irradiated by X-rays have smaller mass shrinkage compared with the ones which were not irradiated, so they were more preserved. The dose of X-rays which can be used to preserve was around (3-5) $x10^{-14}$ Gy. This banana preservation gives opportunities to improve the quality of the exported banana.

5. Acknowledgement

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