

Application of Cold Storage for Raja Sere Banana (*Musa acuminata colla*)

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Abstract. Raja Sere is one of the indigenous banana cultivars in Indonesia. This cultivar has a yellow color when ripen, small size and sweet taste. Traditionally, the growers market this banana cultivar to the market without any treatment to delay the ripening process. Banana fruits are commonly being harvested at the condition of hard green mature. At this condition of hard green mature, banana fruits can be stored for a long-term period. The objective of this study was to examine the effect of cold storage on the quality of raja sere banana that stored at 13°C. Banana fruits cultivar Raja Sere were harvested from local farmer field at the condition of hard green mature (about 14 weeks age after the flower bloom). Fifteen bunches of banana were stored in cold storage with a temperature of 13°C for 0, 3, 6, 9, and 12 days, respectively. For the control, room temperature storage (28°C) was used. At a storage period, samples of banana fruits ripened in the ripening chamber by injecting 100 ppm of ethylene gas at 25°C for 24 hours. The quality parameters namely respiration rate, hardness, total soluble solids (TSS), change in color, and weight loss were measured. For those banana fruits stored at room temperature, the shelf-life of banana was only reached up to 6 days. For those banana fruits stored in cold storage, the condition of banana fruits was reached up to 12 days. After cold storage and ripening, the third day measurement was the optimal time for bananas to be consumed which indicated by the yellow color (lightness value = 68.51, a* = 4.74 and value b* = 62.63), TSS 24.30 °Brix and hardness 0.48 kgf, weight loss about 7.53-16.45% and CO₂ respiration rate of 100.37 mLCO₂/ kg.hr.

1. Introduction

Banana is one of the fruits that has a complete nutrient content, can be consumed by all age levels at any times. Bananas can be used as an alternative source of carbohydrates because they contain high carbohydrates. Also, bananas contain vitamin A, B₁, B₂, B₆, B₁₂ and vitamin C. Bananas can be consumed as a fresh fruit or processed into snacks, such as banana chips, fried bananas, boiled bananas and juice [1,2].

The problems often encountered in bananas are susceptible to damage and decay due to the respiration process, and ethylene produced itself, so it cannot be stored for longer and cannot reach a wider marketing area. Postharvest handling of bananas among farmers, traders or exporters still needs to be repaired because there are still many neglected, causing bananas that reached the consumers have low quality and short shelf-life, so the impact on the selling price and consumer acceptance will also decrease. Generally, parameters of banana quality, namely have a perfect shape, same maturity level, bright fruit skin tone, smooth, fruit flesh is not flabby and good aroma and taste. Preferably, banana is



harvested in mature green conditions so that distribution can reach the other regions, countries and also the maturation can be controlled.

Banana is climacteric fruits that in maturation stage marked by increase a peak of respiration rate and ethylene production, as well as changes in composition, discoloration, fruit softening and aroma production [3]. In climacteric fruits, the respiration process continues after the fruit is harvested and will continue the maturation process. Bananas are also included in perishable fruit, especially during the transportation and distribution process, so that the good post-harvest handling is required.

Raja Sere banana (*Musa acuminata* colla var Raja sere) is one of the indigenous banana that has much demand by the consumers because it can be consumed in fresh form and easy to find. Also, Raja Sere banana has a special aroma, good taste, and a small size so easy to consume directly and has a fairly high economic value. However, post-harvest handling of Raja Sere banana still has problems, especially among farmers who harvest not by the age of harvest-time and post-harvest handling is still not good cause banana has a low selling value and short shelf-life relatively due to the low quality of bananas. Banana damage can happen since from the field, during the process of transportation and distribution, and post-harvest handling so that it affects the acceptance of consumers.

Therefore, post-harvest handling is needed to maintain the quality of bananas, forms, taste, texture and nutritional content, to fulfill of consumers demand for longer periods of time and can be reached to a wider area by delayed the ripening process and maintaining the mature green of bananas so not to ripen quickly during storage. One way that can be used to extend banana shelf life is low-temperature storage. [4] stated that the temperature of bananas during storage and transportation ranges from 13-14°C with RH 90-95% because it can inhibit metabolism process, to slow the maturation process, extend the shelf-life of banana and also at that temperature banana will avoid from chilling injury [5].

According to [6], storage at low temperatures can decrease biochemical reactions that occur in fruit, inhibit respiration rate, reduce of ethylene production and it works and inhibits the process of softening the fruit flesh so that it can extend the shelf life of the fruit. [7], stated that based on the simulation model obtained, the tolerance of maturation delay (storage) of Ambon bananas at 15°C and then substituted with the addition of 100 ppm ethylene could reach up to 30 days of shelf life. Therefore, it is also necessary to do a low-temperature storage on the Raja Sere banana to extend the shelf life and overcome the problems that faced by banana growers, traders, and consumers to keep the good quality. The objectives of this study were to examine the effect cold storage for banana fruits cultivar Raja Sere on the changes in the quality after ripening process.

2. Materials and methods

The study was conducted in two stages, preliminary research conducted in September 2016 and the main research was conducted in November 2016 until February 2017 at the Laboratory of Food Processing and Agricultural Products (TPPHP) Department of Machinery and Biosystem Technology, Faculty of Agricultural Technology, Bogor Agricultural Institute. The storage temperature consists of two temperatures, i.e., room temperature (28°C) as control and low-temperature 13°C, the storage period of 0, 3, 6, 9, and 12 days and each treatment was carried out in three replications. The quality parameters measured after the ripening with ethylene, namely respiration rate, total soluble solids, firmness, color, and weight loss.

3. Results and discussion

3.1. Respiration Rate

The respiration rate during cold storage is relatively stable compared to banana storage at room temperature [10]. The results of the study in figure 1 show that the respiration rate of Raja Sere banana leaves a pattern of respiration of climacteric fruits. After ripening, measurement of quality parameters is only done until day four because, after that day, the fruit has been threshed.

Banana respiration rate (figure 1) after ripening on 0-day storage has the highest respiration rate on the third day after ripening, which was 102.05 mLCO₂/kg.hr. Banana respiration rate on three days

storage at room temperature, after ripening has the highest value of CO₂ respiration rate on the third day, that is 120.99 mLCO₂/kg.h, while at 13°C storage occurs on the 4th day, that is 59, 91 mLCO₂/kg.hr). After 6 days storage at room temperature and at 13°C, the highest respiration rate after ripening was on day 3, i.e. 117.74 mLCO₂/kg.h (room temperature) and 89.79 mLCO₂/kg.h (13°C). At the storage temperature of 13°C for 9 days and 12 days, the rate of banana respiration after peak ripening occurred on the 3rd day, which was 115.83 mLCO₂/kg.h (storage 9 days) and 100.37 mLCO₂ / kg.h on second day (12 days storage).

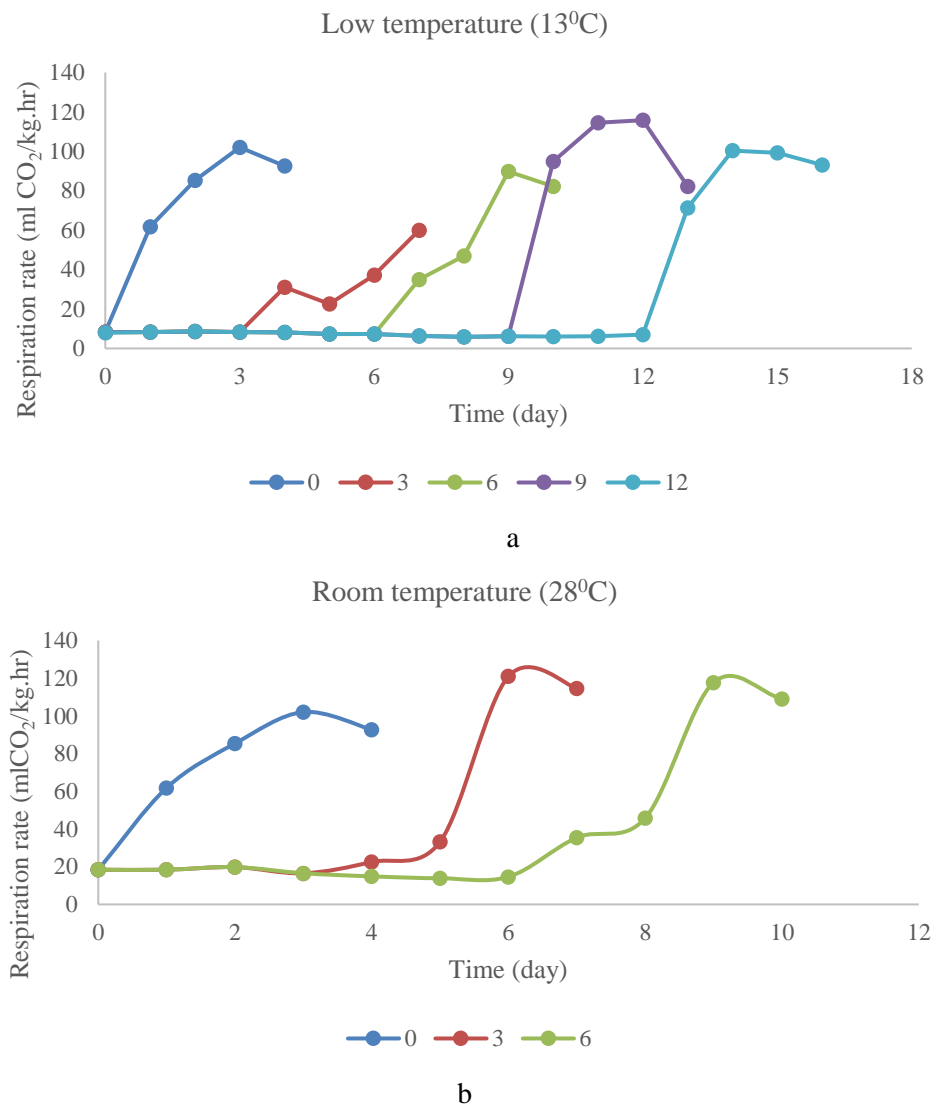


Figure 1. Respiration rate (mLCO₂/kg.h) of Raja Sere banana after storage time and ripening for a) 0, 3, 6, 9, and 12 days at 13°C and b) 0, 3, and 6 days at room temperature

Cold storage can inhibit metabolic processes (transpiration, respiration, ethylene production) in bananas so that the maturation process can be slowed down. Bananas storage at room temperature (28°C) is only able to survive until the sixth day, while cold storage (13°C) can survive until the twelfth day. After ripening with ethylene, it further promotes the internal ethylene production of the banana itself and accelerates the maturation process, both stored at 13°C and 28°C and increasing respiration rates characterized by an increase in the amount of CO₂ concentration [11]. Threshing fruits after ripening showed the fruit has begun to senescence (already past the optimal of eating time).

3.2. Total Soluble Solid

The total soluble solids (TSS) of Raja Sere banana that has been ripened getting higher every day of measurement. This is because, during storage and maturation there will be a change of starch into sugars (sucrose, glucose, and fructose) which is soluble in water [12]. According [10], banana cv. Raja buluh have a total soluble solid that continue to increase from storage to maturation, which ranges from 18-32°Brix. The increase in total soluble solid during ripening may result from an increase in the concentration of organic solutes as a consequence of water loss. The increase may also be possible due to numerous anabolic and catabolic process taking place in the fruit preparing it for senescence [13].

The total soluble solids of Raja Sere banana at room temperature ranged from 13.4 - 24.67 °Brix (on storage 0 days to 6 days storage), whereas at cold temperatures ranged from 13.4 to 24.30 °Brix (on storage 0 days up to 12 days storage) (figure 2). The increase in total soluble solids occurring at room temperature occurs due to high-temperature differences, leading to chemical reactions and faster breakdown of carbohydrates by enzymes [14].

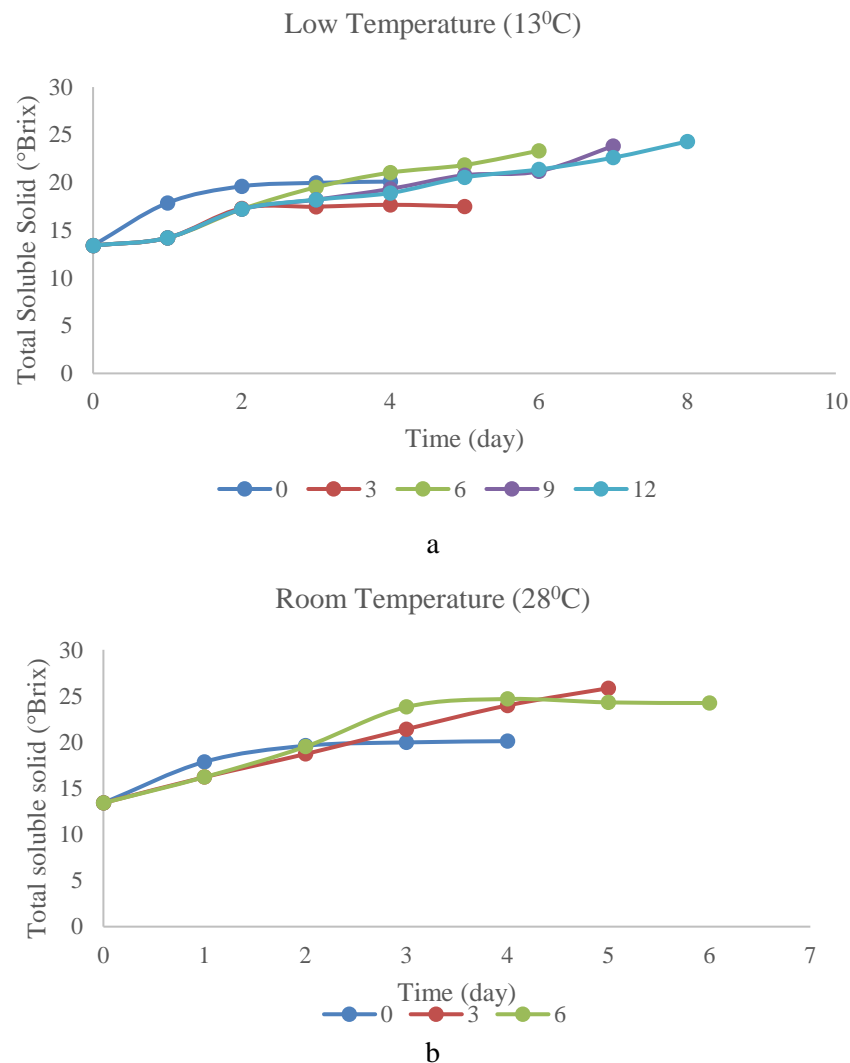


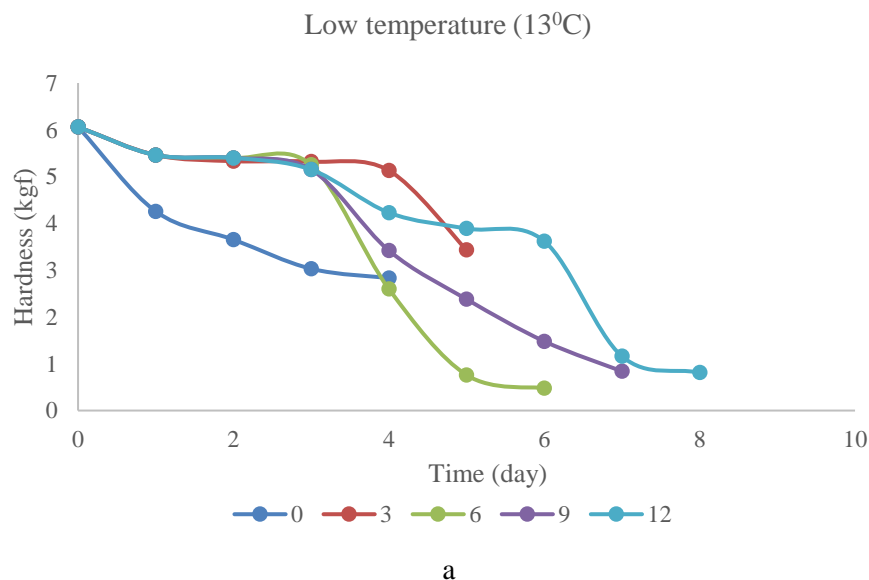
Figure 2. Total soluble solids of Raja Sere banana after storage time and ripening for a) 0, 3, 6, 9, and 12 days at 13°C temperature and b) 0, 3, and 6 days at room temperature

According to [15], an ethylene-injected on banana will have a total soluble solid larger than un-injected bananas. Also, bananas stored at higher temperatures will result in higher total soluble solids (22.1 °Brix) compared to bananas stored at low temperatures (21.1 °Brix). This is by the measurement data obtained that the bananas stored at room temperature (28°C) are higher than the total soluble solids rather than at low temperatures (13°C). Increasing of total soluble solid was related with other parameters, such as the increase in weight loss that caused by the hydrolysis of starch into simple sugars, the decreasing hardness value is also caused by the hydrolysis of starch that causes the flesh of banana will soften than before.

3.3. Firmness

Firmness is one of the most crucial factors in determining the post-harvest quality of fruits, as banana. The level of banana firmness indicates the level of banana maturity. The more mature banana, the firmness of the flesh fruit will decrease (more softened) because during the process of maturation occurs the reshuffle of starch into sugar and wall cell reshuffle [15]. According to [13] said that the decrease in firmness, during ripening may be due to breakdown of insoluble protopectin into soluble pectin or by cellular disintegration leading to membrane permeability. The hard or semi-hard banana fruits are not liked by most of the consumers. Therefore, to develop desirable quality, the banana fruits need to be ripened artificially for enhancing consumer acceptability. The value of firmness of Raja Sere banana after the ripening continues to decrease every day of measurement.

The value of firmness at room temperature storage ranged from 0.36 - 6.06 kgf, whereas in cold storage 0.81 - 6.06 kgf. The highest firmness value is in initial storage, which is 6.06 kgf, while the lowest is in 6 days storage (room temperature) and 12 days (temperature 13°C) (figure 3). This occurs because during storage also occurs metabolic processes such as transpiration, respiration, breakdown of cell walls, although it is slow and will be faster after ripening.



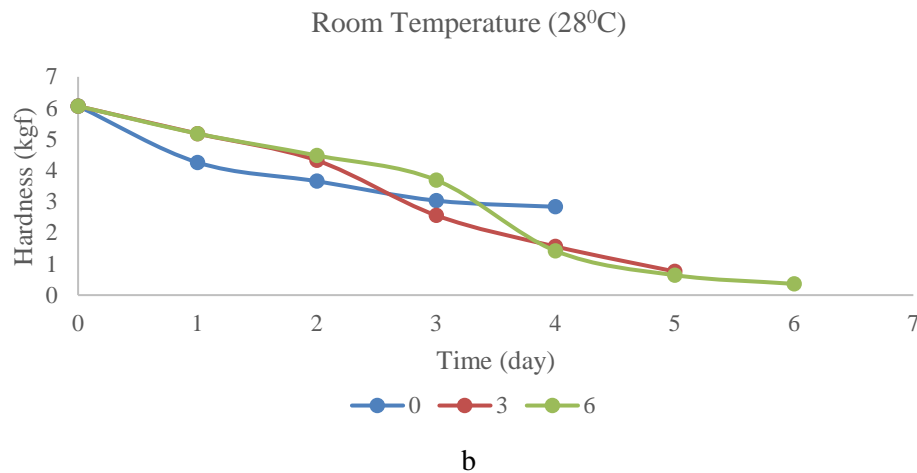


Figure 3. The firmness value of Raja Sere banana after storage time and ripening for a) 0, 3, 6, 9, and 12 days at 13°C temperature and b) 0, 3, and 6 days at room temperature

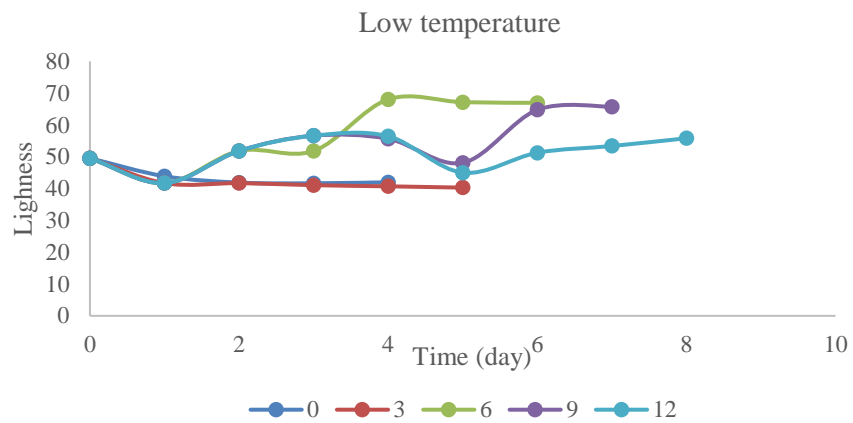
The injection of ethylene on banana ripening can accelerate the softening of banana flesh compared with bananas without ethylene [11]. The higher the temperature of banana ripening, the lower effect of ethylene being injected against the softening of the fruit flesh because as long as the storage of bananas stored at high temperatures has produced internal ethylene.

According to [16], softening of banana flesh can occur with three processes, including the conversion of starch into sugar, the breakdown of pectin components and the movement of water from the skin of the fruit to the flesh during the maturation process. Bananas stored for 3 days have a higher firmness value than 6, 9, and 12 days storage. This proves that storage duration affects the firmness of bananas after ripening. In addition to the long-term storage, storage temperature also affects the firmness value. The other opinion come from [17], that said that hydrolysis of starch to sugar during ripening causes an increase in osmotic pressure is usually associated with a decrease in turgor pressure which may account for shortening during ripening and would cause the firmness decrease.

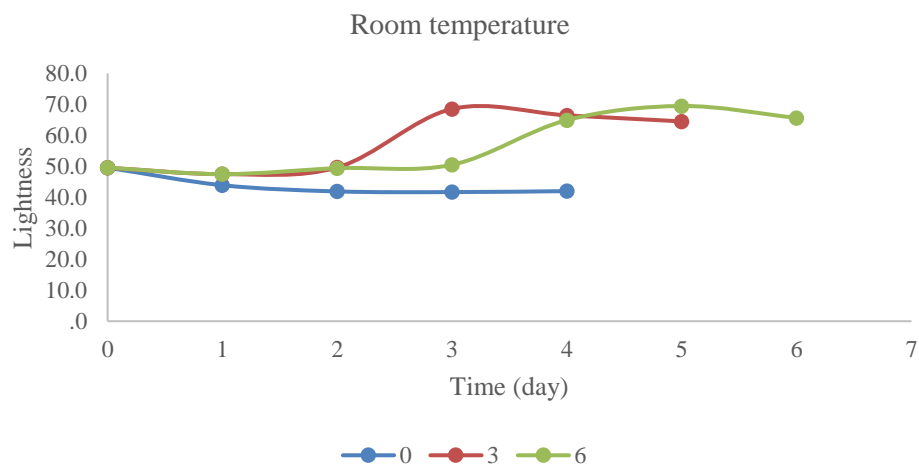
According to [15], fruit size also determines the fruit firmness, because of the smaller size of fruit the faster the occurrence of decomposition of sugar and starch content during maturation, thus accelerating the process of banana maturation of smaller size than larger. It is also supported by research conducted by [18] which states that smaller tomatoes will have a higher total soluble solid value than large tomatoes because the smaller size of the fruit the easier it will be to degrade the sugar and starch in the fruit. Decreasing level of banana firmness associated with the increasing value of total soluble solids.

3.4. Color

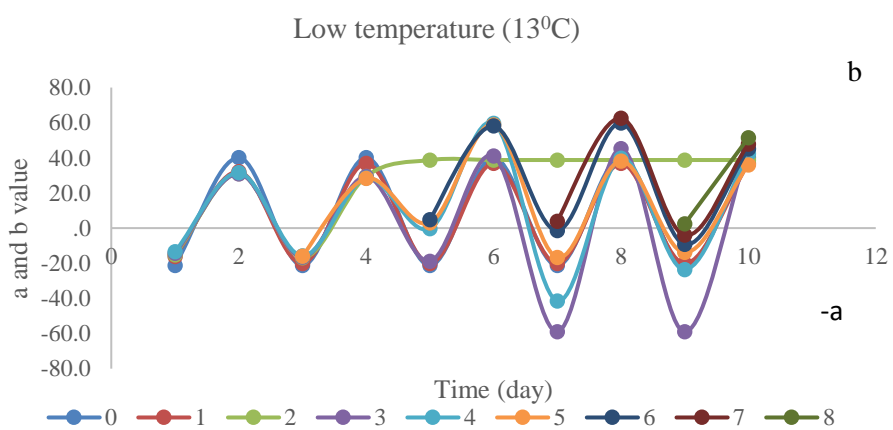
The color parameter is the crucial parameter of consumer acceptance. During storage, the measurement of color to the value of Lightness (brightness), a value, and b value to determine the level of maturation of bananas (figure 4). The color of bananas at 13°C did not change too much, which is still green with maturity index 1 (green) in accordance with the index of banana maturity [19], while storage at room temperature, bananas began to change color on the 15th day to yellow with a maturity index of 4, ie more yellow than green, so it was decided to store temperature in 13°C temperature for 12 days.



a



b



b

-a

c

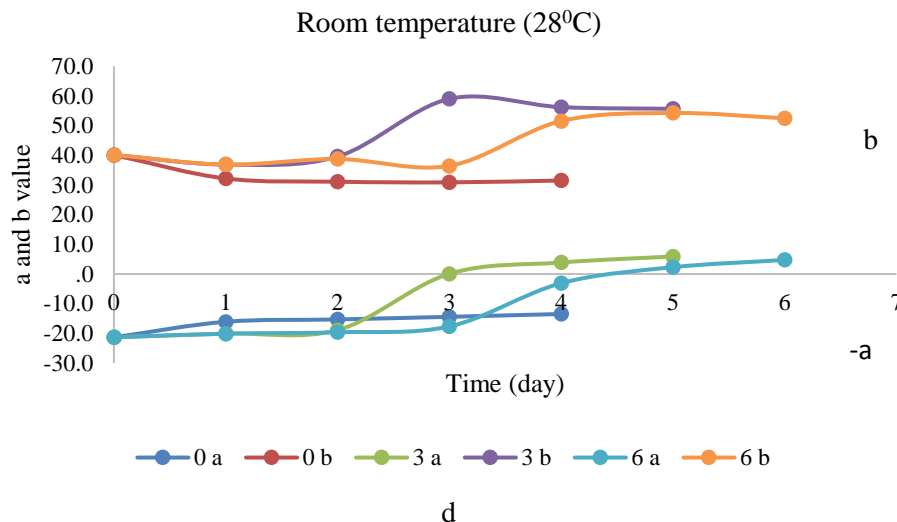


Figure 4. The color (Lightness, a and b value) of Raja Sere banana after storage time and ripening for (a and c) 0, 3, 6, 9, and 12 days at 13°C temperature and (b and d) 0, 3, and 6 days at room temperature

The change of banana skin color from green to yellow is due to the degradation of chlorophyll (green pigment) to a carotenoid (yellow pigment). Degradation of chlorophyll occurs immediately near the climacteric peak of fruit [20]. According to Burg and Burg (1965) in [21], states that ethylene has an effect on the degradation of chlorophyll during maturation, that also said by [13] that ethylene gas is known to accelerate the chlorophyll degradation and induce yellowness in green tissue of many fruits. The rate of degradation of banana chlorophyll along with the increase in temperature [12] also as [22 & 23] said that banana fruit has a unique contradiction compared to the most other fruits, which degreens at a faster rate at higher temperature. According to [24], the amount of chlorophyll during the maturation decreases to zero and then during the senescence period, enzyme activity becomes high and then dark color will cover the skin of the fruit (the fruit becomes rotten).

3.5. Weight loss

During storage, bananas are heavily weighted due to a chemical component degradation. Weight loss in 13°C temperature storage is lower (constant) than to room temperature storage. It proves that the higher the temperature storage of the fruit, the greater weight loss activity. Weight loss caused by the metabolism process in banana tissue. Respiration and transpiration play an important role in the shrinkage of banana weight. According to [15], smaller bananas will experience greater transpiration and respiration than larger bananas, causing a high weight loss. Raja Sere banana is a small banana fruit, with a fruit length of 10-15 cm [2].

The value of weight loss at room temperature storage ranged from 6.25 to 10.67%, while at storage temperature 13°C 7.53-13.05% after storage for 12 days. During observation 4 days after ripening, the weight loss of banana was smaller after storage at room temperature compared with storage at 13°C. This is because, during storage at room temperature, the weight loss of weight occurs greater than at the storage temperature of 13°C (figure 5).

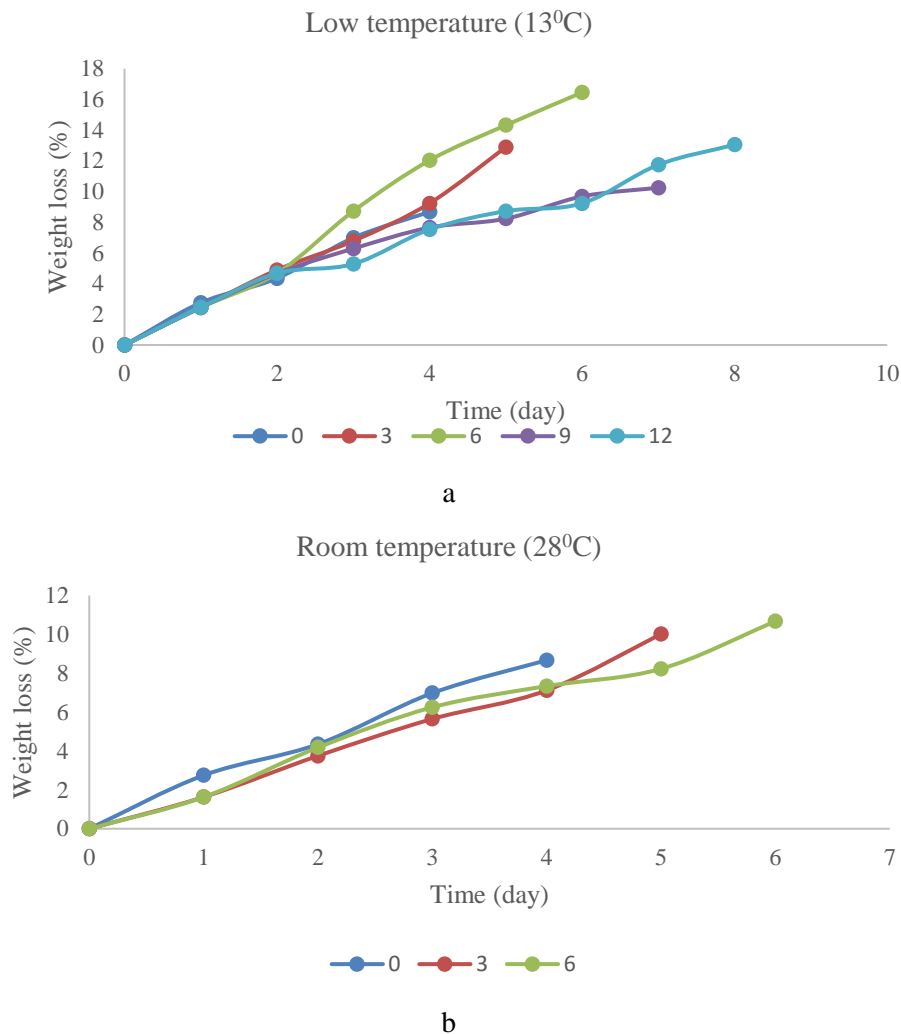


Figure 5. The weight loss of Raja Sere banana after storage time and ripening for a) 0, 3, 6, 9, and 12 days at 13°C temperature and b) 0, 3, and six days at room temperature

According to [25], the softening of fruit texture is a major process of ripening, leading to a loss of firmness, facilitating pathogen infection, increasing postharvest decay, and reducing shelf-life and fruit quality. It also is shown that the weight loss of banana fruit will increase as long as ripening process. The weight loss of banana fruit was increased as long as the storage-time so it also can show that the quality of banana decreased or come into the senescence process. The weight loss parameter is related to the firmness parameter, the firmness will decrease so the weight loss will high.

4. Conclusions

The conclusion from this study:

1. Storage of Raja Sere banana at room temperature can only reached up to 6 days, while at 13°C reached 12 days.
2. The longer the storage time was done, the value of firmness will decrease. Otherwise the total soluble solids and weight loss will higher and will decrease when starting to senescence.
3. The 3rd day after-ripening is the optimal eating time of banana with the total soluble solids of 24.30°Brix, hardness of 0.36 kgf and full yellow color ($a^* = 4.74$ and $b^* = 52.49$).

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