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Effect of Hot Water Treatment on Quality and Shelf-Life of Rambutan

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Abstract: Rambutan is a non-climacteric fruit and must be harvested at the peak of ripeness. Fruit browning and decay can occur 1 to 3 days after harvest and during storage and transportation. Hot water treatment holds promise for delaying the postharvest fruit quality decay and reducing pathogen growth. This research aims to investigate the effects of incorporating hot water treatment and temperature-controlled storage on the postharvest quality of rambutans. Rambutan fruit was treated in a hot water bath at 40° and 50°C for 0, 2, 4, 6, 8, and 10 minutes. Then, it was stored for 8 days at ambient (28–30°C) and controlled (10–18°C) temperatures. Combined hot water treatment and controlled storage temperature was an effective approach for managing postharvest decay, controlling postharvest diseases and insect pests, and maintaining the postharvest quality of the rambutan fruit. Rambutan fruit treated with hot water (40–50°C) for 6–10 minutes and stored at controlled temperature (10–18°C) could remain fresh for more than 8 days after harvest.

Keywords: hot water treatment, rambutan, temperature storage, quality.

热水处理对红毛丹品质和保质期的影响

摘要：红毛丹是一种非更年期的水果，必须在成熟高峰时收获。收获后以及储藏和运输过程中，水果会发生褐变和腐烂 1 至 3 天。热水处理有望延缓采后果实品质的下降并减少病原体的生长。这项研究旨在调查结合热水处理和温度控制的存储对红毛丹收获后品质的影响。红毛丹果实在 40°摄氏度和 50 摄氏的热水浴中处理 0、2、4、6、8 和 10 分钟。然后，将其在环境温度（28–30 摄氏）和受控温度（10–18 摄氏）下保存 8 天。结合热水处理和可控制的储藏温度是控制采后腐烂，控制采后病虫害和保持红毛丹果实采后质量的有效方法。红毛丹果实用热水（40–50 摄氏）处理 6–10 分钟并保存在受控温度（10–18 摄氏）下，可以在收获后保持新鲜 8 天以上。

关键词：热水处理，红毛丹，温度存储，质量。

1. Introduction

Rambutan (*Nephelium lappaceum* L.) is an important tropical fruit commonly grown in Southeast Asia. Recently, the leading producers and exporters of rambutan fruit have been Thailand, Malaysia, and Indonesia [1]. In 2018, Indonesia produced 715,935 tons of rambutan, increasing from 523,704 tons in 2017 [2]. It has an exotic appearance and contains many vitamins, amino acids, carbohydrates, and a variety of minerals [3]. Rambutan has the potential to be developed as a profitable crop because it contains many compounds that are good for human health.

Generally, rambutan is consumed fresh. Rambutan is non-climacteric and must be harvested at maximum ripeness because further ripening does not continue after harvest [4]. It is harvested when the fruit has reached optimum visual appearance (red or yellow

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color) and a suitable quality for eating. Rambutan, like other horticultural commodities, is very easily damaged and has a relatively short shelf life [5]. Browning and decay can occur 1 to 3 days after harvest and during storage and transportation. The peel color and spinterns darken during storage. Moreover, postharvest diseases also limit the successful marketing and export of rambutans [6]. Supapvanich [7] reported that released juice and pulp softening are other key factors affecting consumer acceptance.

Hot water treatment is an effective approach for managing postharvest quality, controlling postharvest diseases and insect pests, and alleviating chilling injury to fruits and vegetables. Several works reported that hot water treatment can inhibit postharvest decay in zucchini [8], mangoes [9], tomatoes [10], [11], papayas [12], potatoes [13], grapes [14], mature green mumes [15], and other fruits and vegetables. Generally, postharvest handling of rambutans uses modified atmosphere packaging or enhanced CO_2 atmosphere (9–12%) packaging to maintain appearance [5], and lukewarm water dips to maintain postharvest quality and nutritional value [7]. However, lack of study about the combination of hot water treatment and temperature storage on rambutans to manage postharvest decay and extend their shelf life. This research aims to investigate the effects of incorporating hot water treatment and temperature storage treatment on the postharvest quality of rambutans.

2. Materials and Methods

2.1. Materials

Rambutan (*Nephelium lappaceum* L.) cultivar LebakBulus was obtained from Subang Regency, West Java, Indonesia. The equipment used included a water bath, refrigerator, digital scales, oven, and others. The study was conducted at the Indonesian Center for Agricultural Postharvest Research and Development.

2.2. Methods

2.2.1. Raw Material Preparation

Rambutans were harvested in the afternoon at the peak of the ripeness stage, as determined by redness of pericarpcolor, then sorted based on uniformity of ripeness, color, and fruit size. Subsequently, they were screened again, and those free from physical damage, insect attack, and disease were selected. The sorted rambutans were placed in a plastic basket, delivered to the laboratory, and immediately treated with hot water.

2.2.2. Treatments Applications

Rambutan fruits were soaked in a hot water bath at 40°C (x_1) and 50°C (x_2) for 0 (y_1), 2 (y_2), 4 (y_3), 6 (y_4), 8 (y_5), and 10 (y_6) minutes, then drained. After that, the rambutan fruit was packed in 0.03 mm thick polyethylene bags, which had been perforated six times with a paper hole punch. Each package contained eight fruits. The fruit was stored for 8 days at ambient temperature (28–30°C) (z_1) and controlled temperature (10–18°C) (z_2).

2.2.3. Parameters

2.2.3.1. Moisture Content [16]

The moisture content was determined using the oven drying method. A total of 5 g of crushed rambutan fruit samples were heated in an oven at 105°C for 5 hours, cooled in a desiccator, and weighed.

2.2.3.2. Weight Loss [17]

Weight loss measurement was carried out using digital scales. Measurements were made before the rambutan fruit was stored (b_o) and each time it was observed (b_t). The value of weight loss is obtained by subtracting the weight of the stored fruit on day t (b_t) from the initial weight (b_o), which was expressed as a percentage (%). Weight loss measurements were carried out on storage days 0, 1, 2, 3, 4, 5, 6, 7, and 8. The formula used to measure weight loss is:

$W = ((b_o - b_t)/b_o) \times 100\%$.

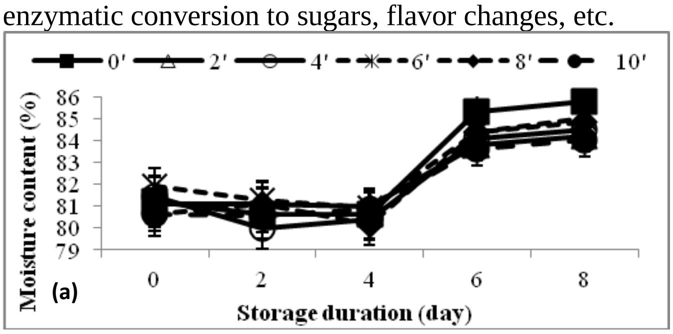
2.2.3.3. Respiration Rate [17]

Measurement of CO_2 and O_2 concentrations in the sample gas were carried out using a gas analyzer (Felix F-950, Three Gas Analyser, Felix Instruments, Camas, WA, USA) by allowing air to flow from a sealed glass bottle into the gas analyzer at a rate of 70 mL/minute. Measurement of the respiration rate (CO_2 production) of the fruit was carried out at 23°C and 85% relative humidity using a closed method. One fruit was placed separately in a 2 L sealed glass bottle for 1 hour. The respiration rate was expressed as CO_2 production in mL kg^{-1} h^{-1}. All data were processed using Excel.

3. Results and Discussion

3.1. Moisture Content

Moisture content is an indicator of fruit freshness. It is an important factor affecting its tenderness, taste, freshness, and flavor [17]. Like most horticultural products, harvested rambutan still undergoes metabolism, namely respiration and transpiration. This metabolic process can cause water evaporation, enzymatic conversion to sugars, flavor changes, etc.



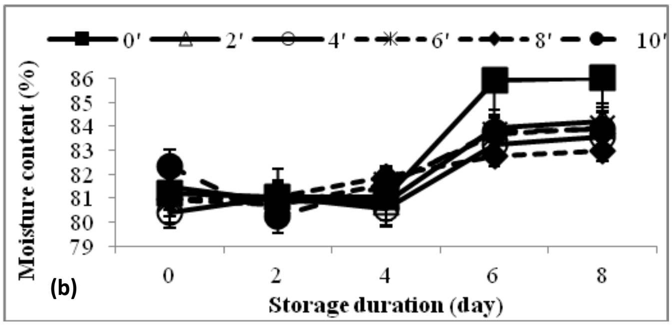


Fig. 1 The moisture content of rambutan stored at ambient temperature (28-30°C), after the dipping process at temperature: a) 40°C and b) 50°C

Rambutan is a fruit with a large number of stomata. The spintern surface of rambutan has five times more stomata than the pericarp surface [18]. Having so many stomata on the surface of the fruit can hasten fruit transpiration even if stored at low temperatures. Mota et al. [4] reported that decreases in the moisture content of rambutan were mainly caused by moisture loss from the pericarp, specifically through the spinterns. The high surface area to volume ratio of the spintern (hairy nature) partly accounts for its high propensity for moisture loss.

Transpiration that continues after the fruit is harvested also contributes to its rapid loss of water and freshness during storage. Fruit transpiration has a positive correlation with fruit respiration rate. Transpiration requires heat energy, which is the result of the respiration process, and then water vapor moves out of the fruit through the stomata [19]. Respiration produces heat, which can cause a further increase in heat, so that the process of water loss, withering, and growth of microorganisms will increase.

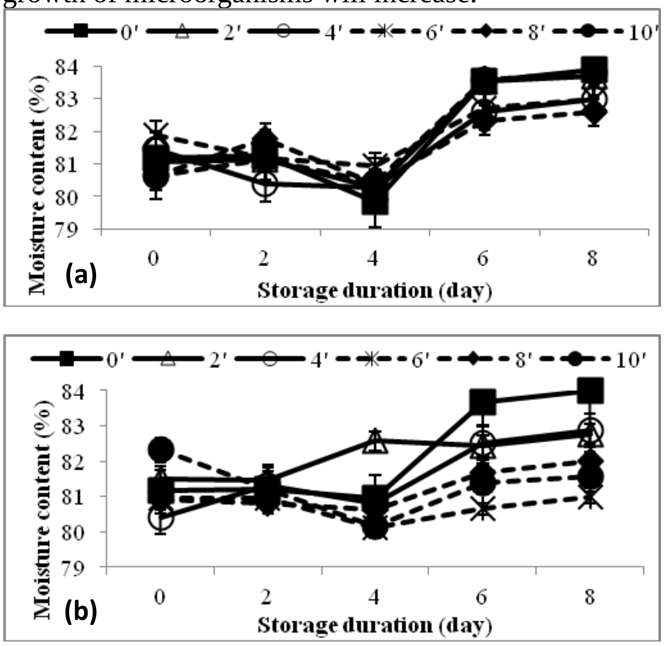


Fig. 2 The moisture content of rambutan stored at controlled temperature (10-18°C), after the dipping process at temperature: a) 40°C and b) 50°C

Overall, the water content of rambutan during storage tended to be constant during storage (80–86%). The moisture content of rambutan during storage tended to decrease until the 4th day and then increased again until the 8th day of storage. The rambutans were thought to have lost water up to the 4th day, during the storage period. This is because, the respiration process occurs during the storage process, which causes the growth of microorganisms which can be detected by increasing the moisture content. Based on Figs. 1 and 2, the moisture content of the rambutans began to increase on the 6th day of storage, indicating that the microorganisms began to grow on the 6th day of storage as well. In general, rotten microorganisms obtain optimal growth conditions with an increase in temperature and humidity and can infect vegetables through existing lesions.

The moisture content of the rambutan fruit treated with hot water tended to decrease more slowly than without hot water treatment (control). This reinforces the argument that hot water treatment can slow down the process of respiration and transpiration in rambutans, thereby slowing the decrease of moisture content and maintaining the freshness of the rambutans during storage. Chiabrando & Giacalone [14] stated that hot water treatment is promising for delaying the postharvest fruit quality decay, or to reduce the pathogens' growth; this treatment inhibited the microbial growth during storage. This statement confirmed the research result of [20], which stated that hot water treatment has a significant effect on the log reduction of *S. enterica* and *E. coli.*

Moisture loss during storage not only causes weight loss, but also has the potential to damage, which ultimately results in lower quality. To a certain extent, the moisture loss does not have much effect on the quality of the material product, but when it reaches a minimum water loss, it can cause wilting and wrinkling, making the appearance less attractive, the texture soft, and ultimately a decrease in quality [12].

3.2. Weight Loss

Measurement of weight loss is generally used as the basis for measuring the quantity of horticultural products during storage [13]. At the beginning of storage, rambutan's weight loss at ambient temperatures ranges from 0.65 to 1.79%, while the weight loss of rambutan stored at ambient temperatures ranges from 0.28 to 3.19%. After 12 days of storage, the weight loss of rambutan stored at ambient temperatures ranges from 6.03 to 11.76%, while the weight loss of rambutan stored at ambient temperatures ranges from 10.16 to 15.28%.

Weight loss also occurs due to respiration and transpiration, which causes horticultural commodities to reduce their food reserves and lose water through evaporation. During respiration, carbohydrates, proteins, fats, and other nutrients in the product are broken down into simpler substances by releasing heat energy, where the energy produced is not fully utilized by the product. However, most of it is lost in the form of heat that spreads to the environment [21], so that along with the length of storage, the food reserves contained in the fruit will decrease, which results in increased weight loss.

Hot water treatments significantly reduced the rate of weight loss in rambutan. The weight loss is essentially due to respiration and water transpiration rates. Hot water treatment can slow down the process of respiration and transpiration [8]. Rambutan with hot water treatment has respiration and transpiration process slower than without hot water treatment. This causes rambutan treated with hot water to have weight loss lower than rambutan without treated hot water.

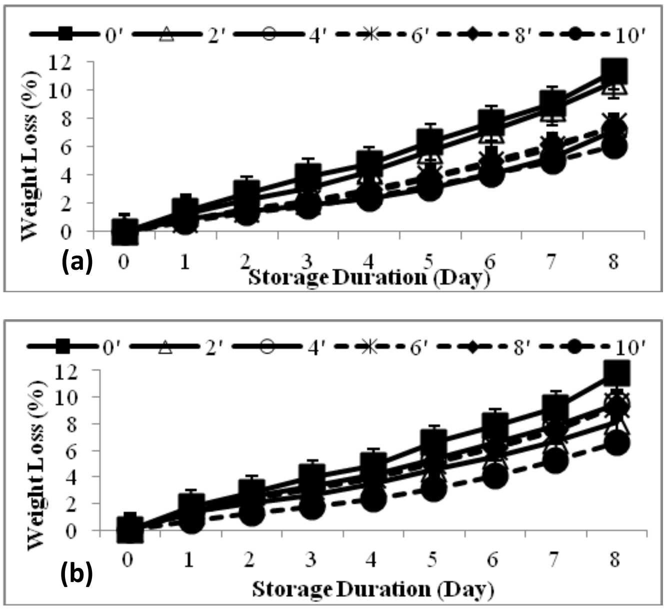


Fig. 3 Weight loss of rambutan stored at ambient temperature (28-30ºC), after the dipping process at temperature: a) 40ºC and b) 50ºC

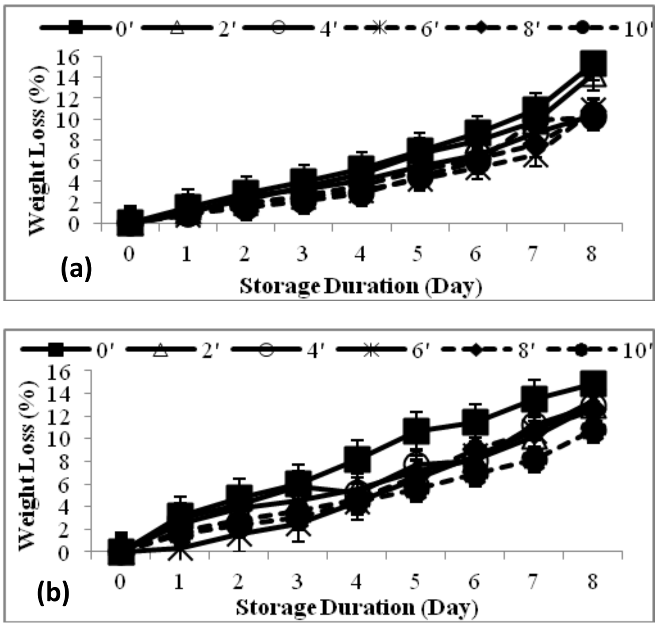


Fig. 4 Weight loss of rambutan stored at controlled temperature (10-18ºC), after the dipping process at temperature: a) 40ºC and b) 50ºC

Low-temperature storage is one of the most widely used post-harvest technologies and can extend horticultural crops' shelf life [15]. However, temperature storage after hot water treatments did not have an effect on weight loss of rambutan during storage. This is in line with the research results of Chávez-Sánchez et al. [22], which state that antifungal hot water treatment at 55°C for 0, 3, 6, and 9 minutes at 25°C storage temperatures has no effect on weight loss of papaya fruits. In addition, Bassal & El-hamahmy [23] also stated that the hot water dipping treatment at 41°C for 20 minutes or 50°C for 5 minutes with the initial storage condition of 6 days at 16-18°C and RH 45-65% had no effect on the weight loss of citrus fruit.

Weight loss in rambutan occurs mainly as moisture loss from the pericarp. Furthermore, fruit are unmarketable at weight losses greater than 25% [4]. Based on this statement, rambutan with hot water treatment is marketable for 12 days of storage.

3.3. Respiration Rate

The respiration rate can be influenced by internal factors such as cultivar; growing season and region; and the maturity stage. External factors can also influence this, such as temperature, oxygen concentrations, carbon dioxide concentrations, and others [24]. Furthermore, the respiration rate is generally determined from the quantification of O_2 consumed and CO_2 produced by the product [25]. The potential shelf life of horticultural products after harvest has been shown to be closely related to their respiration rate [26].

The process of fruit ripening is normally viewed distinctly in climacteric and non-climateric fruits, according to their respiratory patterns. The term "climacteric" was initially proposed to indicate the dramatic increase in respiration (rise in the production level of CO_2) of fruit during ripening [19]. In contrast, non-climacteric fruits do not show a dramatic change in respiration, CO_2 or ethylene production [27]. Based on this statement, rambutan as a non-climacteric fruit does not undergo a dramatic increase in respiration during ripening. Otherwise, this statement was inconsistent with our results, which has shown that rambutan do not show a dramatic increase in respiration and production of CO_2. Although rambutan is a non-climacteric fruit, it demonstrates a climacteric pattern.

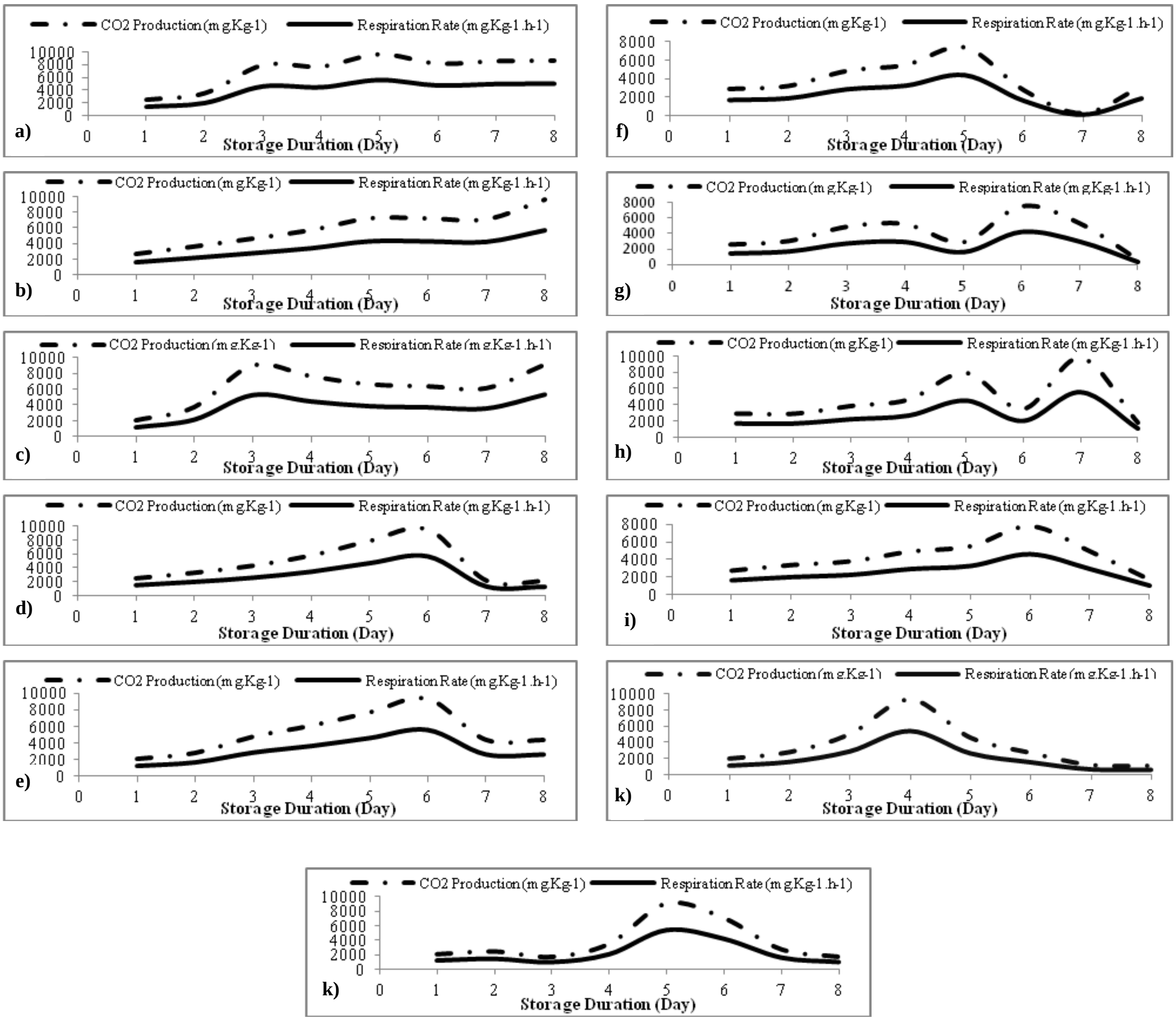
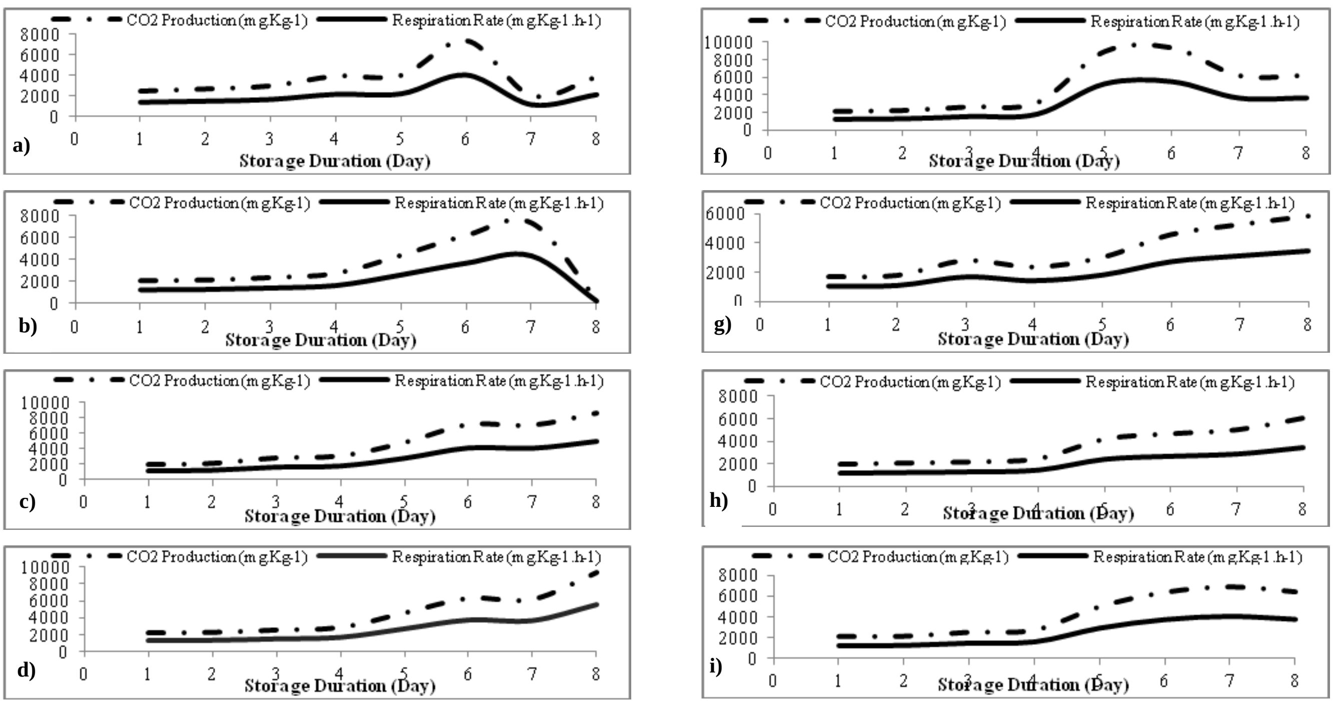


Fig. 5 CO_2 production and respiration rate of rambutan stored at ambient temperature with dipping treatment: a)40°C for 2'; b) 40°C for 4'; c) 40°C for 6'; d) 40°C for 8'; e) 40°C for 10'; f) 50°C for 2'; g) 50°C for 4'; h) 50°C for 6'; i) 50°C for 8'; j) 50°C for 10'; and k) without dipping



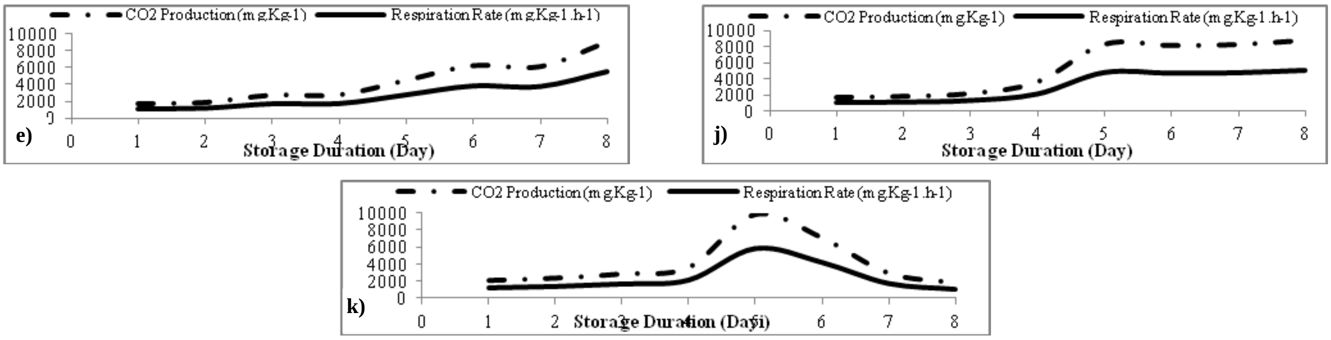


Fig. 6 CO_2 production and respiration rate of rambutan stored at controlled temperature with dipping treatment: a)40ºC for 2'; b) 40ºC for 4'; c) 40ºC for 6'; d) 40ºC for 8'; e) 40ºC for 10'; f) 50ºC for 2'; g) 50ºC for 4'; h) 50ºC for 6'; i) 50ºC for 8'; j) 50ºC for 10'; and k) without dipping

Symons et al. [28] stated that ripening is a complex process which must be very tightly regulated. This process includes the changes in color, flavor, texture and aroma. The classification of fruits into climacteric and non-climacteric categories is an oversimplification. The results indicated that comparative analysis of plant-attached and plant-detached fruits did not show similarity in their ripening behavior. Furthermore, there is evidence that climacteric and non-climacteric fruits have some similar pathways of ripening.

The CO_2 production and respiration rate of rambutan without hot water treatment and stored at ambient temperature increase from day 3 until day 5, then decline after day 5 until day 8 (Fig. 5k). The peak of respiration rate represents the ripening of fruit, while the decline of respiration rate shows the senescence (overripening) of fruit [24]. This means that rambutan without hot water treatment and stored at ambient temperature will reach ripening stage at day 3 until day 5 after harvest, and will become overripe at day 6 until day 8 after harvest. Temperature is one working parameter that affects a lot of processes [29].

The peak of CO_2 production and the respiration rate of rambutan stored at ambient temperature occurred on days four to seven after harvesting (Fig. 5). The CO_2 production of rambutan stored at ambient temperature on day one was 1129.77 to 1724.51 mg. $Kg^{-1}.h^{-1}$. It increased between days four and seven (4456.23 to 5684.50 mg. $Kg^{-1}.h^{-1}$), then declined until day eight (317.05 to 2620.99 mg. $Kg^{-1}.h^{-1}$), except during treatment dipping at 40ºC for two minutes (5009.50 mg. $Kg^{-1}.h^{-1}$), 40ºC for four minutes (5735.00), and 40ºC for six minutes (5331.50 mg. $Kg^{-1}.h^{-1}$). During cell enlargement to the maturation period, CO_2 production of rambutan fruit will decrease, then continue to increase during the ripening period until peaking. The respiration rate and CO_2 production of three treatments (Figs. 5a, 5b, and 5c) still increased eight days after harvesting. Therefore, this treatment can extend the shelf life of rambutan fruit.

The respiration rate depends on storage temperature and the availability of oxygen required for respiration [30]. Several studies on tropical fruits have also demonstrated the same results, namely the higher the level of ripeness and storage temperature, the higher the respiration rate. A high respiration rate causes short shelf life. Conversely, a slow respiration rate will lead to a long shelf life [25].

Rambutan stored at a controlled temperature (without hot water treatment) had a longer shelf life than stored at ambient temperature. The CO_2 production and respiration rate of rambutan without hot water treatment and stored at a controlled temperature increased at day four until day five, then declined after day five until day eight (Fig. 6k). Thus, rambutan without hot water treatment and stored at a controlled temperature had a ripening stage of between days four and five after harvesting; they were ready to overripen six to eight days after being harvested.

A combination of hot water treatment and storage temperature could extend the shelf life and maintain the quality of the fruit. The peak of CO_2 production and the respiration rate of rambutan stored at a controlled temperature occurred on day four and remained almost stable until day eight after harvesting (Figs. 6c–6j). Therefore, this treatment could extend the shelf life of rambutan fruit for more than eight days after harvesting.

The hot water treatment for rambutan can be used directly for the preparation of fruit for supermarkets and the fresh fruit market, both of which require high-quality produce. However, the export market may require other quarantine treatment for pest and disease control if this one alone is not adequate. For high quantity treatment, it is necessary to have a device that can maintain the temperature during treatments and does not fluctuate.

4. Conclusion

A combination of hot water treatment and storage temperature is an effective approach for managing postharvest decay, controlling postharvest diseases and insect pests, and maintaining the postharvest quality of rambutan fruit. Rambutan fruit that receives hot water treatment of 40–50ºC for between six and 10 minutes and stored at a controlled temperature (10–18ºC) can maintain its freshness and extend its shelf life for more than eight days after harvesting.

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