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Research article

Identification of Respiratory Patterns and Quality Assessment Between Melons Inodorus and Cantalupensis Groups

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Abstract

Two econommically significant melon groups, inodorus and cantalupensis, exhibit distinct differences in their respiration activity, which can significantly affect their postharvest quality and storage behavior. Identifying the two groups of melons is essential for determining the most effective postharvest handling practices. The aims of this study were to reveal the respiratory patterns of inodorus and cantalupensis melon-groups and to investigate their relationship to fruit quality for informing optimal postharvest handling. The treatments used were two groups of melons, inodorus and cantalupensis, with five replications (each treatment used three melon fruit samples). The fruit was stored in a modified drum with lighting, CO_2 detector, temperature and humidity detector, and had been sterilized. The data were analyzed using F-test and mean comparisons with standard deviation. Subsequently, a post-hoc LSD was applied to identify significant differences and Pearson correlation was employed to examine the relationship among the parameters observed. The results indicated that CO_2 concentration influenced the respiration rate and affected the fruit's physical and nutritional characteristics. Cantalupensis exhibited a higher respiration rate than inodorus, leading to a shorter shelf life and a more noticeable decline in fruit quality. There was a positive correlation between CO_2 and respiration rate (R= 0.28), causing reduced edible parts, total soluble solids (TSS), water content, and vitamin C in both melon groups. This study highlights that the respiratory patterns of the two melon groups differ, with cantalupensis being climacteric and inodorus non-climacteric. Therefore, tailoring of the postharvest handling practices for the two melon groups is required to prevent significant quality loss.

Keywords: CO_2 concentration; fruit quality; horticulture; postharvest handling; respiration

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1. Introduction

Agricultural products have problems in various aspects, not only on the farm but also after harvesting. Inappropriate postharvest handling causes increasing yield loss and decreasing product value. Kasso and Bekele (2018) stated that the causes of yield loss included microbial infection, fruit ripening processes, and inappropriate environmental conditions. Meanwhile, inappropriate postharvest handling in melons is associated with harvesting methods, harvest times, harvest processing, storage, transportation, and distribution of fruit yield (Strano et al., 2022). Furthermore, yield losses in horticultural products on and off the farm reached 20%-50% (Tiwari et al., 2020). This condition has an impact on the availability of agricultural products and the product value.

Melon is one of the horticultural products that has a perishable trait (easily injured) when it has been harvested (Widyasanti et al., 2017). The injury in melon fruit is due to mechanical damage such as impacts, falls, or the density in the storage containers (Azam et al., 2022). Mechanical damage during storage causes a decline in TSS and titratable acidity, while the pH of the fruit flesh remains relatively stable (Salomão et al., 2016). Additionally, fungal infections can cause rapid decay, and activation of cell wall-degrading enzymes, such as *polygalacturonase* and *galactanase,* contribute to a loss of fruit flesh firmness (Zhang et al., 2024). This condition causes a decrease in fruit quality and an increase in the percentage of yield loss. In melon fruits, there are two economically significant melon groups, namely cantalupensis and inodorus, which have different respiratory patterns (Leida et al., 2015). As we know, there are two groups of respiratory patterns in horticultural products, namely climacteric and non-climacteric. Climacteric is a condition that has high ethylene hormones, while non-climacteric is a condition with low ethylene production (Chen et al., 2018). The characteristics of the indoor group are smooth peel with yellow color (without a net) and an average weight ranging from 1.5 to 2 kg. The fruit is oval, and its flesh is not domed (Chikh-Rouhou et al., 2021). In contrast, the cantalupensis group is round with netted peel, soft and textured flesh, and higher water content. Additionally, the flesh of cantalupensis has a distinct aroma (Ayres et al., 2019).

Farmers generally use the same postharvest handling method for all melon groups without considering the differences in their respiratory pattern. However, a horticultural product with different respiratory patterns may well require different postharvest handling activities. This is because the quality of agricultural products of the climacteric type could easily be decreased due to their high respiration rate (Farcuh et al., 2018). In contrast, products of the non-climacteric groups are less likely to experience a decline in quality because their respiration rate remains low. Hence, if non-climacteric melons undergo harvesting before they are fully ripe, the likelihood of an increase in their respiration rate is low (Silva et al., 2024).

The respiratory pattern in melon fruits depends on the melon-type; climacteric and non-climacteric) (Stroka et al., 2024). Melons with a climacteric type have a high respiration rate, and melons require oxygen (O_2) to break down organic compounds into carbon dioxide (CO_2), water (H_2O), and energy (Krupa & Tomala, 2021). As for non-climacteric, the melons have a low respiration rate, so the ripening process is slow. Ethylene is a hormone that triggers the ripening process and plays a role in the metabolism activity of fruits (Yu et al., 2024). The high respiration rate is influenced by the high levels of ethylene hormone. Melons that have a fast ripe process mean they have a high respiration rate with high levels of ethylene hormones.

Previous studies primarily focused on identifying the physicochemical characteristics of various melon groups. In contrast, in this study, the melon respiratory

pattern and its relationship with ethylene production alongside the physicochemical characteristics of the melons were investigated. The urgency and novelty of this study lied in its exploration of respiratory pattern and their relationship with fruit quality in two distinct melon groups. This study could be a foundational strategy for determining appropriate postharvest handling practices for melons by identifying their respiratory patterns. The findings would be helpful for farmers in order to reduce yield loss, minimize product injury, and optimize melon handling techniques. Additionally, this study could provide valuable insight for farmers, researchers, and academics in advancing postharvest technology for melons. The respiratory patterns of two melon groups and their relationship to fruit quality for appropriate postharvest handling were focused in this study.

2. Materials and Methods

The study was conducted from April to July 2024 at the Laboratory of the Faculty of Agriculture, Universitas Perjuangan Tasikmalaya. The ethylene content was analyzed at the Laboratory of PT. Saraswanti Indo Genetec, Bogor, Indonesia.

2.1 Procedures

The study used a completely randomized design with a single factor, namely the type of melon with two levels: cantalupensis and inodorus. There were five replications, and each replication used three melon fruits. The details of the study stages are presented in Figure 1. Three melons in each treatment were placed in a drum that had been modified using a light, air hose, and CO_2 detector, as shown in Figure 2. The hose functioned as part of the measurement of respiration rate, which was based on the capture of CO_2 by 0.05 N NaOH. Melons were harvested directly from the gardens in Central Java, Indonesia, and sorted based on shape, color, and weight uniformity. Melons from the inodorus group typically weighed approximately 1.6 kg, while those from the cantalupensis group ranged from 1.3 to 1.5 kg. In the cantalupensis group, we used melons with thick netted rind, whereas in the inodorus group, we used a perfectly yellow hue. After sorting and grading, the melons were stored in a modified storage room. Before storage, the storage drums were thoroughly cleaned with technical acetone as part of an environmental sanitation process to ensure the fruit remained free from microbial contamination during storage.

The temperature and air humidity conditions in the storage during the study were observed every day and the data obtained are shown in Figures 3a and 3b. Based on these data, the temperature during modified storage fluctuated, and ranged between 26^{o}C-30^{o}C in the cantalupensis melons and 25.7^{o}C-29.6^{o}C in the inodorus melons. Furthermore, the air humidity in melon-type cantalupensis between 83% - 95.8%, and melon-type inodorus between 75.6%-97.5%. These data illustrate that the modified fruit storage conditions are comparable to room temperature, which is also influenced by fruit respiration activity. Therefore, the storage condition experienced fluctuations in temperature and air humidity.

2.2 Variables observed

The CO_2 concentration was observed using CO_2 detector type S8808 placed on each drum. Temperature and air humidity values were observed using thermohygrometer type HTC-2 digital thermohygrometer. Titrimetric method was used for the measurement of respiration rate according to the method conducted by Widyanti et al. (2022). Melon

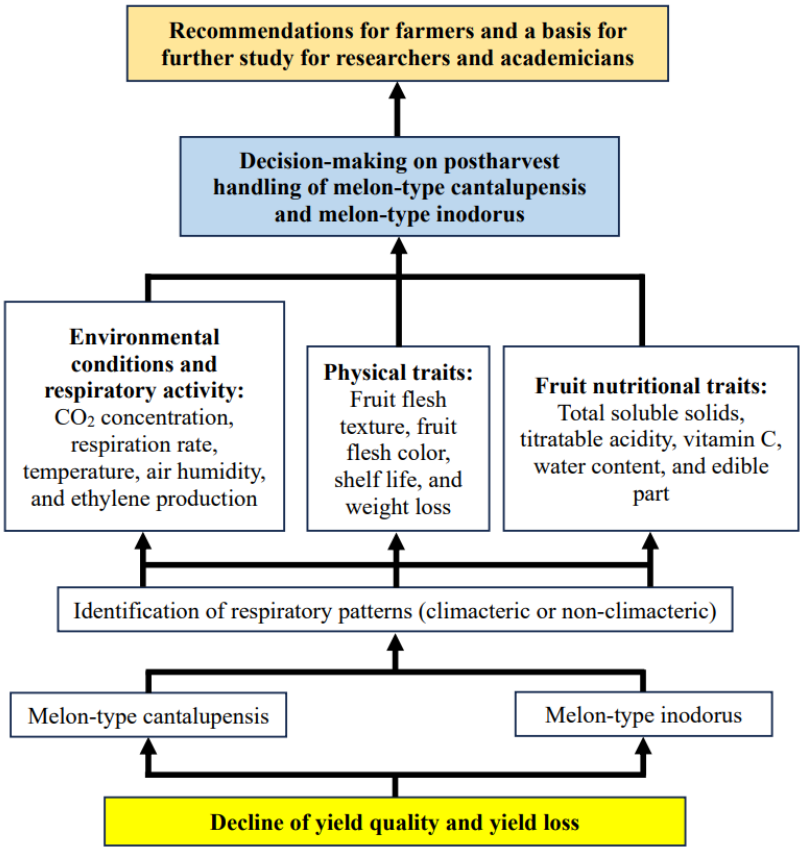

Figure 1. Study stages flowchart

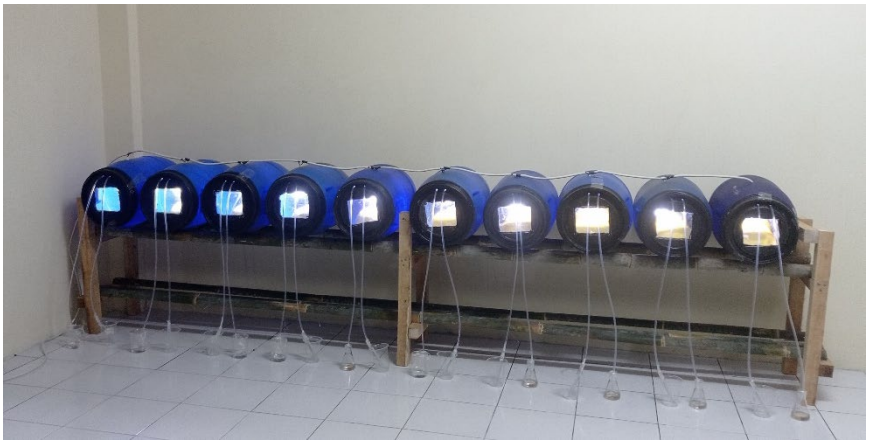

Figure 2. Modified drum as a storage for melon samples

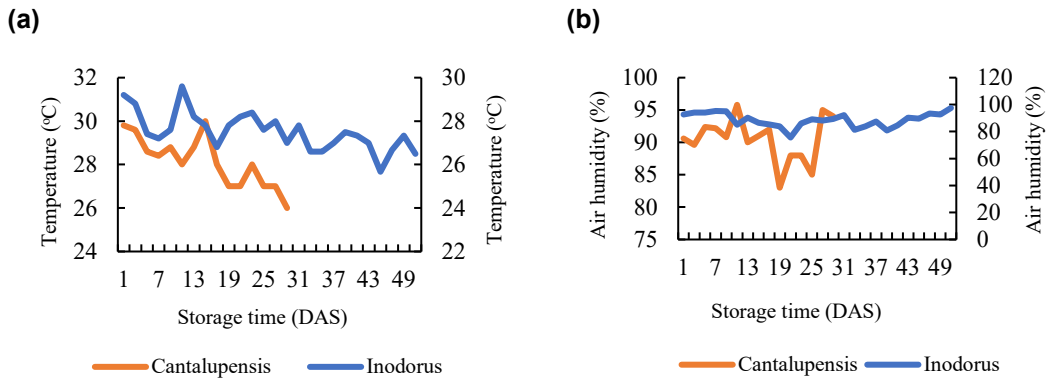

Figure 3. (a) Temperature storage; and (b) Air humidity in the modified storage during the study

samples were placed into modified drums fitted with plastic tubing. After that, the samples were exposed to an airflow at a rate of 1 L min-1 for 2 min, with the air first passing through a saturated 0.1 N $Ca(OH)_2$ solution. The air then passed through 25 mL of 0.05 N NaOH solution. A titration was performed using 5 mL of 0.05 N NaOH solution, followed by adding as much as 3 drips of 0.1% phenolphthalein indicator, and then titrated with 0.05 N HCl until the red color disappeared. A blank solution underwent titration with 0.05 N HCl as a concentration factor, then following formula in equation 1 served to determine the respiration rate. Fruit weight was weighed using a digital scale with an accuracy of 0.01 x 2.000 g.

$$\text{Respiration rate (mg/kg/h)} = \frac{\text{(mL blank - mL sample) x NHCl x molecul weight of } CO_2}{\text{2 x melon weight (kg) x time ()}} \quad (1)$$

The edible part of the fruits was determined using the method described in Widodo et al. (2019). Water content was determined by weighing the fresh fruit using a digital scale, followed by drying in a Memmert Type UN 260 oven at 80°C for 48 h. After the drying process, rewighed the fruit using the digital scale. The determination of vitamin C was made according to the method suggested by Tyl and Sadler (2017). The TSS content was determined with a digital refractometer HI96831. Ethylene production was assayed according to Tran et al. (2013): a 5.0 g sample was weighed into a 50 mL polypropylene centrifuge tube with the addition of 20 mL of methanol. The mixture was shaken vigorously in a grinder at 1000 strokes per minute for 2 min, followed by a centrifuge at 4000 rpm for 10 min. Ethylene determination followed the method outlined by Farczádi et al. (2022). Melon samples underwent homogenization, and 100 mg portions were extracted with 20 mM ammonium formate containing an internal standard using ultrasonication, followed by centrifugation. Preparation of ethephon calibration standards (10 µg mL^{-1}) involved dilution of stock solutions. Analytes were detected using LC-MS/MS in negative electrospray ionization and multiple reaction monitoring (MRM) mode. No chromatographic separation was applied. The mobile phase included 40:60 methanol to 20 mM ammonium formate (v/v), delivered isocratically at 0.1 mL min^{-1}. The injection volume was 10 µL with a total run time of 3 min per sample. Fruit weight and shelf life were calculated manually based on the time the fruit was stored until it was no longer suitable for consumption.

2.3 Statictical analysis

The quantitative data was analyzed using F-test and mean test with standard deviation. Further testing of the least significant difference (α= 5%) was used if there were differences between treatments. Pearson correlation was used to reveal the relationship between the observed parameters. All data analysis was done using Microsoft Excel and Statistical Tools for Agricultural Research version 2.0.1.

3. Results and Discussion

Horticultural products such as melons are sensitive traits and can easily be injured if not handled properly (Widyasanti et al., 2017). Inappropriate postharvest handling causes a decline in yield quality and can affect yield losses of up to 50% (Tiwari et al., 2020). Moreover, melons can be divided into two groups based on respiratory patterns. Their respiratory type certainly affects the shelf life, fruit quality, and postharvest technology that needs to be applied.

The respiration activity of melon fruit is affected by the CO_2 concentration during the storage process (Fang & Wakisaka, 2021). Figure 4a indicates that the CO_2 concentration during the first 15 days in cantalupensis-type melon tended to increase and decrease until the 29th day. Furthermore, the respiration rate of cantalupensis-type melon increased during the storage process to a very high level and then decreased as the fruit became unfit for consumption. This condition causes the breakdown of food reserves in the fruit flesh, which affects the weight loss and fruit quality (Lufu et al., 2019). Meanwhile, the CO_2 concentration in inodorus-type melons was relatively more stable and increased when the fruit became unfit for consumption. The respiration rate also tended to be stable and increased as the fruit aged. Both CO_2 concentration and respiration rate showed that cantalupensis and inodorus melon types required different handling. Paul et al. (2012) stated that fruit with high respiration rate is classified as climacteric, and fruit with low respiration rate is classified as non-climacteric. In climacteric fruits, ethylene production increases, leading to a significant elevation in the respiration rate (Tipu & Sherif, 2024). This enhanced respiration rate in harvested climacteric fruits results in reduced shelf life and a deterioration in quality (Asrey et al., 2023). In contrast, non-climacteric fruits do not show a significant increase in ethylene production and respiration rate during ripening (Wang et al., 2022). The ripening process in these fruits is regulated by ethylene-independent mechanisms, including hormones such as abscisic acid (ABA), auxin, and gibberelllin, which collectively play key roles in regulating fruit maturation (Fuentes et al., 2019).

Melons with different respiratory patterns affect physical and nutritional traits (Obando-Ulloa et al., 2008). In this study, an evaluation of the physical and nutritional traits was carried out at three points, namely when the fruit began to be stored, in the middle of storage, and when the fruit was almost unfit for consumption. During storage, both groups of melons experienced a decrease in edible fruit flesh, which was observed by looking at the edible part. Cantalupensis-type and inodorus-type melons showed a decrease in edible fruit flesh of 23.68% and 11.66%, respectively (Figure 5a). The decrease in edible parts was due to the high breakdown of food reserves attributed to the activity of the respiration rate (Pham et al., 2023). The high respiration rate experienced by cantalupensis caused a higher decrease in edible parts. Furthermore, due to the high decrease in the edible parts, there was an increase in the water content of the fruit. The cantalupensis melons

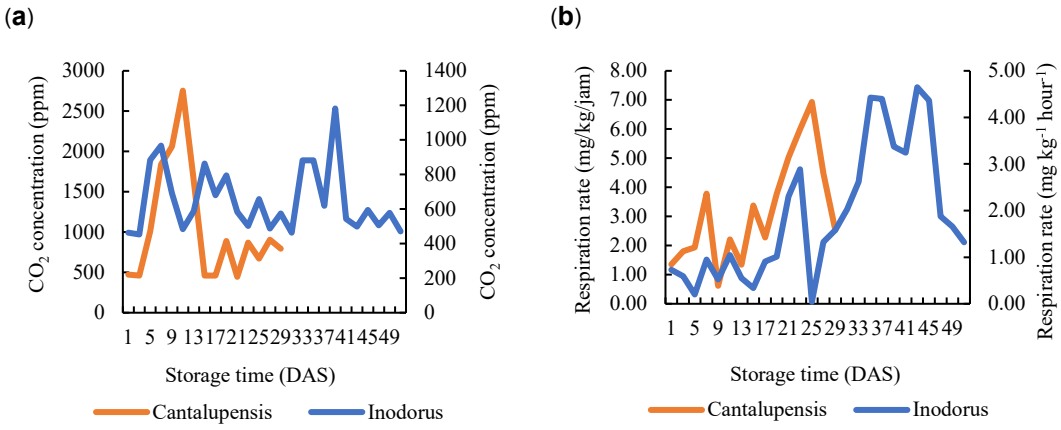

Figure 4. (a) CO_2 concentration; (b) Respiration rate in two groups of melon during storage

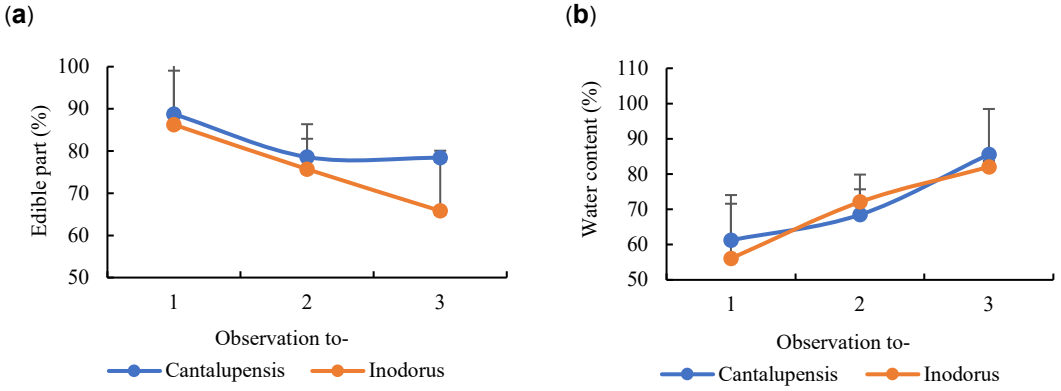

Figure 5. (a) Edible part; and (b) Water content of two melon groups during modified storage

Note: observations of the edible part and water content were conducted at three distinct stages: at the beginning of storage (1), midway through the storage period (2), and when the fruit was no longer suitable for consumption (3).

experienced an increase in water content of 30.52% compared to 28.42% for inodorus melons (Figure 5b). An increase in water levels from respiratory rate was due to the increased breakdown of carbohydrates by utilizing O_2 to produce CO_2 and water (Brizzolara et al., 2020). Increased respiration rates lead to the degradation of cell walls, which results in the breakdown of their components, ultimately weakening the structural integrity of the cell walls (Moya-León et al., 2019). This degradation process also facilitates the formation of compounds such as pectin, which bind water in the fruit tissue, thereby contributing to increased water content (Hou et al., 2022), and consequently, causing

biochemical changes and decrease of fruit firmness (Liu et al., 2021). These conditions significantly impact the postharvest handling practices. Inadequate or improper postharvest handling can lead to a decline in fruit quality, reduced shelf life, weight loss (Gidado et al., 2024), and heightened susceptibility to pathogen invasion (Zhao et al., 2020).

The breakdown of food reserves due to respiration during storage also affected the fruit weight loss (Figure 6). The fruit weight of the inodorus group decreased by 8.74% over 52 days, whereas the cantalupensis group experienced a more pronounced decrease of 10.99% within a shorter duration of just 28 days. The cantalupensis type experienced higher weight loss, which was influenced by the higher respiration rate associated with their climacteric nature (Kasim et al., 2022). The higher weight loss affects the faster shelf life (Pham et al., 2023), which represents a decline in fruit quality (Krupa & Tomala, 2021). The shelf life of two groups of melons is presented in Table 1.

Table 1 shows that the cantalupensis melons had a shorter shelf life than the inodorus. Fruit with climacteric traits have a shorter shelf life than non-climacteric (Pham et al., 2023). This condition results from accelerated metabolic processes, including ripening and senescence, driven by increased ethylene production. The rapid ripening occurs due to high energy consumption, which leads to quick softening, nutrient degradation, and moisture loss. These physiological changes, combined with tissue degradation, facilitate microbial growth and contribute to the further decline in fruit quality and shelf life (Hasan et al., 2024). In Table 1, ethylene production analyzed at the start of storage time for both cantalupensis and inodorus was the same (0.00312 mg kg^{-1}). Fruit with high water content is very susceptible to injury by microbes so enzyme activity and the entire metabolic process cannot be stopped (Moon et al., 2020). High water content creates favorable conditions for the growth of spoilage microbial, including fungi and bacteria, which can contribute to postharvest decay and pose potential health hazard (Zhao et al., 2020). As a result, fruit ripens more rapidly and undergoes a decline in quality during storage, which may negatively affect consumer preference. Changes in various metabolic activities in the two groups of melons also caused a reduction of TSS and vitamin C.

Figure 7 showed that both groups of melons experienced a decrease in TSS: 13.56% in the cantalupensis-type and 9.09% in the inodorus-type. A decrease in TSS is related to the sweet taste of melon fruits (Aini et al., 2023). Higher TSS generally indicates a higher sugar content, contributing to a sweeter taste and playing a crucial role in consumer preference (Yan et al., 2023). Previous studies showed that melons with TSS exceeding 12^{o}Brix were considered satisfactory by consumers, indicating a strong preference for sweeter melons (Lu et al., 2015). The largest decrease in cantalupensis was due to the breakdown of carbohydrates in the respiration process. During ripening, climacteric melon undergo an increase in respiration rate due to increased ethylene production. Enzymes like sucrose phosphate synthase (SPS) and sucrose synthase (SUSY) are responsible for the synthesis and breakdown of sucrose/carbohydrate (Jing et al., 2022). The activity of these enzymes can be affected by temperature (Qiang et al., 2020). As carbohydrates breakdown during respiration, the production of ATP provides energy for various metabolic processes in the fruit. This energy is essential for the synthesis of new compounds, the maintenance of cellular structures, and the support of other physiological functions (Wu et al., 2019). Li et al. (2019) stated that sucrose in melon fruit is reflected in the total soluble solids value and its decrease is caused by metabolic activity that is still ongoing in the climacteric type. The vitamin C content in melons also increased in cantalupensis by 2.03%, while in the inodorus type it decreased by 31.37% (Figures 7a and 7b). Changes in vitamin C content due to free radicals affect the quality of melon fruit (Manchali et al., 2021).

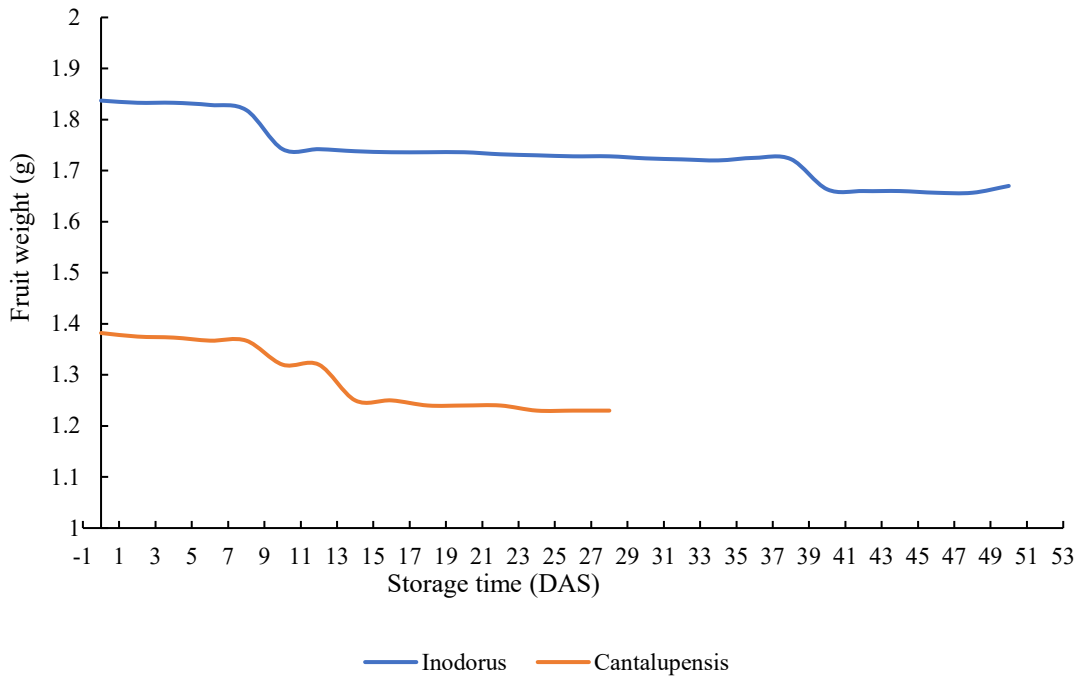

Figure 6. Weight loss in two groups of melons during modified storage

Table 1. Shelf life and ethylene production of two groups of melons during storage

Melon-type	Shelf life (DAS)	Ethylene production (mg kg^{-1})
Cantalupensis	28^{b}	0.00312
Inodorus	50^{a}	0.00312

Note: DAS (days after storage); numbers followed by different letters in the same column are significantly different in the LSD test α= 5%.

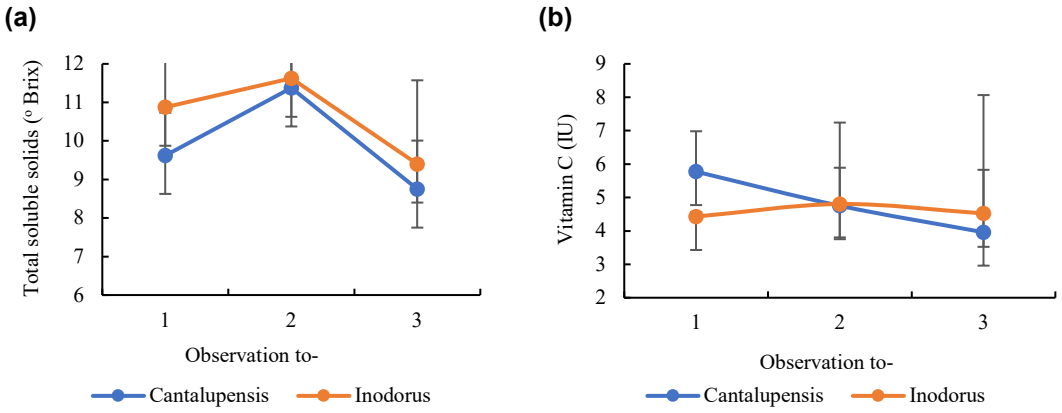

Figure 7. (a) Total soluble solids; and (b) Vitamin C in two groups of melons during storage

Note: observations of the total soluble solids and vitamin C were conducted at three distinct stages, i.e. at the beginning of storage (1), midway through the storage period (2), and when the fruit was no longer suitable for consumption (3).

The correlation analysis in Table 2 showed that the increase in CO_2 concentration caused an increase in respiration rate (R= 0.28) and total soluble solids (R= 0.56). Furthermore, CO_2 concentration caused a decrease in edible parts (R= -0.44) and weight loss (R= -0.68). The study results reveal that high CO_2 concentration was caused by an increase in the respiration rate and affected the decline of edible parts. The decline of edible parts also caused weight loss due to increased respiration (R=-0.82). The degradation of sucrose and all organic components in melon fruit affects the decline in fruit quality and weight loss. This condition causes a decrease in total soluble solids, titratable acidity, and vitamin C (Wu et al., 2020). High respiration is caused by environmental conditions such as temperature and air humidity, which affect the physiological activity of the fruit (Lufu et al., 2019). Previous studies have shown that storing melon fruits at temperature between 0°C-5°C and relative humidity levels of 75%-95% can help reduce microbial contamination, preserve vitamin C, and maintain sensory quality (Jung-Soo et al., 2020). However, temperature rising to 10°C- 20°C can lead to increased weight loss, accelerated pulp softening, color changes in the pulp, and promote microbial growth (Sun et al., 2022).

In the present study, we found that cantalupensis and inodorus melons had different respiratory patterns. The differences between the two were seen from changes in respiration rate, CO_2 concentration, temperature and air humidity, and affected various physical and nutritional traits of melon fruits.

Table 2. Pearson correlation between parameters observed

	CO_2 Concentration	Respiration Rate	Total Soluble Solids	Edible Part	Water Content	Weight Loss
CO_2 concentration	1^{**}	0.28^{*}	0.56^{**}	-0.44^{*}	-0.22^{ns}	-0.68^{**}
Respiration rate		1^{**}	0.37^{*}	-0.39^{*}	-0.44^{*}	-0.82^{**}
Total soluble solids			1^{**}	-0.23^{ns}	-0.79^{**}	-0.39^{*}
Edible part				1^{**}	0.12^{ns}	0.33^{*}
Water content					1^{**}	0.28^{*}
Weight loss						1^{**}

Note: ns means there is no correlation; * means there is significant correlation (α= 5%); ** means there is significant correlation (α= 1%).

4. Conclusions

A key finding from this study was that the of cantalupensis melons were climacteric type whereas the inodorus melons were in non-climacteric type. Both melon types were distinguished based on peel appearance, CO_2 concentration, respiration rate, and temperature and air humidity during storage. As a result, the metabolism activities that occurred in melon fruit during storage affectd the fruit's physical and nutritional traits. Total soluble solids, vitamin C, fruit weight, and edible part contents decreased due to respiration activity.

5. Acknowledgements

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6. Authors' Contribution

Nurul Habibah and Via Nuravivah conducted research and data collection in the laboratory. Ririn Nurmala Sari performed the data analysis, and Rena Komalasari handled the data interpretation. Nasrudin contributed to the formulation of the research concept, experimental design, and supervised data collection. All authors were involved in drafting and reviewing the final manuscript.

7. Conflicts of Interest

The authors have declared that no conflicts of interest exist.

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