

Research Article

Effects of maturity stage and storage temperature on quality and shelf life of abiu (*Pouteria caimito* Radlk.) fruit

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ABSTRACT

Abiu (Pouteria caimito Radlk.) is a tropical fruit with valuable nutrients and bioactive compounds. However, due to its short shelf life, its market is limited. Postharvest handling is necessary to extend abiu shelf life. This study evaluated the effects of harvest maturity and storage temperature on abiu fruit quality. Fruit samples were collected from a farmer's garden in Balumbang Jaya, West Bogor Sub-district, Bogor City. Three harvest maturity stages (half-ripe, three-quarter ripe, and fully ripe) and two storage temperatures (room-temperature and cold) were evaluated. The results showed that the harvest quality of three-quarter ripe abiu did not differ from that of fully ripe abiu. At room-temperature storage, fully ripe abiu could be stored for up to 6 days after harvest (DAH), whereas half-ripe and three-quarter ripe abiu could be stored for up to 8 DAH. Cold storage extended the shelf life of abiu to 10-12 DAH.

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Keywords: fruit ripening; harvest maturity; pre-harvest; sensory evaluation

INTRODUCTION

Abiu (*Pouteria caimito* Radlk.) is a tropical South American plant (Clement, 1989) that is agroclimatically suitable for cultivation in Indonesia. The abiu fruit is attractive in color and sweet in taste, making it suitable for fresh consumption. Abiu fruit also contains various health-beneficial antioxidants, such as ascorbic acid, flavonoids, β -carotene, and phenols (Virgolin et al., 2017), and bioactive compounds, such as 5-hydroxymethyl furfural, 1-methyl-5-fluorouracil, and trans-geranylgeraniol (Arif et al., 2021).

Abiu fruit has a relatively short shelf life of six days (Arif et al., 2022), limiting its marketing to local areas. The fruit life can be extended by harvesting it at the appropriate maturity stage (Arif et al., 2022; Sanches et al., 2017) and cold storage (Istianingsih & Efendi, 2013; Mudyantini et al., 2017).

Harvest maturity affects fruit quality and shelf life. Half-ripe abiu fruit has a longer shelf life (9-10 days) than fully ripe fruit (6 days) (Arif et al., 2022). In addition to harvest maturity, the shelf life of fruit can be extended by storing it at low temperatures. Cold temperatures can slow fruit metabolism, thus delaying the aging process, as in the case of sapodilla (Mudyantini et al., 2017) and star apple (Williams & Benkeblia, 2018).

Information regarding the maturity level of abiu fruit at harvest and its storage temperature is limited. Therefore, this study aimed to evaluate the effects of maturity level and storage temperature on the quality of abiu fruit. The obtained information is expected

to help identify the appropriate maturity level and storage temperature for optimal quality and shelf life of the fruit.

MATERIALS AND METHODS

The experiment was conducted from November 2022 to March 2023 at the Post-Harvest Laboratory of the Department of Agronomy and Horticulture, IPB. The fruit was harvested from 3-4 years old abiu trees in farmers' gardens in Balumbang Jaya sub-district, West Bogor district, Bogor city, at an altitude of ± 300 m above sea level.

The experiment was conducted using a factorial design with harvest maturity and storage temperature as the experimental factors. Harvest maturity was determined based on the percentage of yellow color on the fruit skin (Arif et al., 2022, with modifications) as follows: half-ripe fruit (<25% of the fruit skin was yellow), three-quarter ripe fruit (25-75% of the fruit skin was yellow), and fully ripe fruit (>75% of the fruit skin was yellow) (Figure 1). The storage temperature factor consisted of two levels: cold storage (14-16 °C) and room-temperature storage (26-28 °C). Fruits were selected based on weight (150-250 g) and without mechanical damage (due to impact, pests, and diseases). The fruits were then washed and air-dried. The temperature and humidity were monitored using a temperature & humidity data logger. The humidity at room-temperature storage during the study was recorded at 76.3%, whereas it was 88.1% at cold storage. Nondestructive observations were carried out daily (0-12 days after harvest/DAH), whereas destructive observations were carried out every two days (0, 2, 4, 6, 8, 10, and 12 DAH). Each observation was repeated three times, using two abiu fruits per replication. The total number of abiu fruits required was 270:216 for destructive observations, 36 for nondestructive observations, and 18 for harvest.

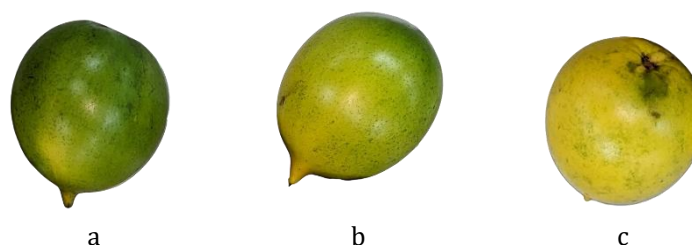


Figure 1. Harvest maturity stages determined by the percentage of yellow skin color: (a) half-ripe, (b) three-quarter ripe, and (c) fully ripe

The evaluated fruit characteristics included CO_2 production ($\text{mg kg}^{-1} \text{ h}^{-1}$), skin color, skin chlorophyll content (mg g^{-1}), weight loss (%), softness ($\text{mm } 50 \text{ g}^{-1} 5 \text{ seconds}^{-1}$), wrinkle level (%), edible portion/EP (%), total soluble solids/TSS ($^{\circ}\text{Brix}$), and titratable acidity/TA (%). CO_2 production was measured using a Cosmotector XP-3140 on incubated fruit in jars for three hours. Skin color was observed using a Munsell Color Chart, and the notation obtained was converted to CIE Lab coordinates using the 'munsellinterpol' package in R. Chlorophyll measurements were performed on skin samples (0.12 g), which were ground and homogenized, and their absorbance was measured using a spectrophotometer. The absorbance values were included in the pigment formula (Sims & Gamon, 2002) to calculate chlorophyll a and chlorophyll b.

Weight loss was calculated by comparing the initial weight with the weight at the time of observation. Fruit softness was measured using a Stanhope Setamatic Penetrometer. Penetration was performed for 5 s with a load of 50 g on three parts of the fruit (base, middle, and tip). The level of wrinkling was scored from 1-8, with the fruit surface divided into eight parts. The EP of the fruit was measured as the proportion of flesh weight relative to whole-fruit weight (after subtracting the weight of the skin, seeds, and columella). The TSS of the fruit was measured using an Atago 3810 PAL-1 hand refractometer, and the TA of the fruit was measured using acid-base titration with 0.1 N NaOH as the titrant and phenolphthalein as an indicator. The observation data were

analyzed using analysis of variance (ANOVA), and treatments that had a significant effect were further tested using Duncan's Multiple Range Test (DMRT) at the 5% level.

RESULTS AND DISCUSSION

Respiration Rate

The harvest maturity stage of abiu fruit, whether stored at cold or room temperature, did not affect CO₂ production (Figure 2), but different times to reach peak CO₂ production were observed. The peak CO₂ production of abiu fruit stored at room temperature occurred sequentially in fully ripe fruit (34.84 mg CO₂ kg⁻¹ h⁻¹, at 6 DAH), three-quarter ripe fruit (28.83 mg CO₂ kg⁻¹ h⁻¹, at 7 DAH), and half-ripe fruit (26.69 mg CO₂ kg⁻¹ h⁻¹, at 9 DAH) (Figure 2b). The peak CO₂ production of fully ripe abiu fruit (day 6) in a previous study was also reported to occur earlier than that of half-ripe fruit (day 8) (Arif et al., 2022).

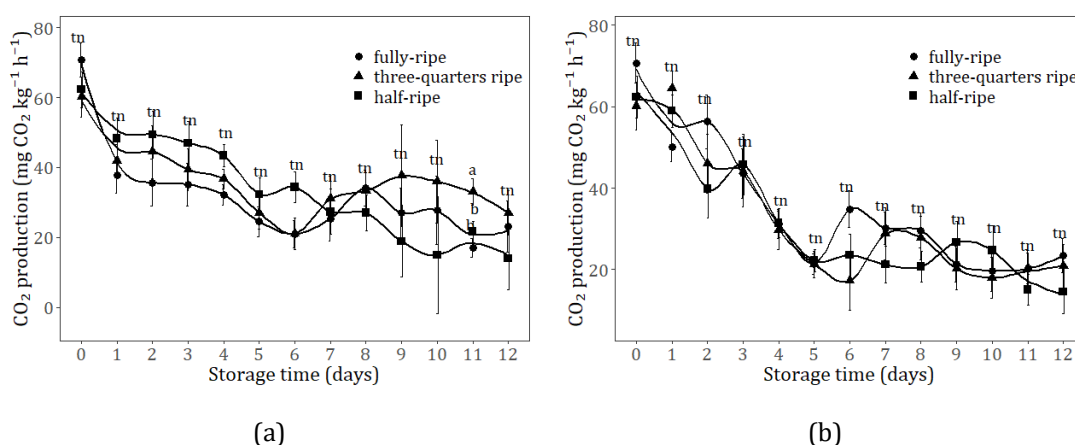


Figure 2. CO₂ production rate of abiu fruit at different harvest maturity stages during storage: (a) cold and (b) room temperature. Values are presented as mean $\pm$ Standard error

The peak CO₂ production of abiu fruit stored under cold storage occurred two days later than that of fruit stored at room temperature; fully ripe fruit reached the peak at 8 DAH (34.16 mg CO₂ kg⁻¹ h⁻¹), and three-quarter ripe fruit reached the peak at 9 DAH (37.60 mg CO₂ kg⁻¹ h⁻¹). In contrast, no peak respiration was observed in half-ripe fruit (Figure 2a). This is in line with previous research showing that cold temperatures can suppress the rate of fruit respiration, such as in sapodilla (Mudyantini et al., 2017) and star apple (Williams & Benkeblia, 2018). Harvesting abiu fruit at the half-ripe and three-quarter ripe stages, as well as storing the abiu fruit in cold storage, can delay the peak CO₂ production, thereby extending the shelf life of abiu fruit.

Fruit Skin Color

Fruit color is a key factor that producers and consumers consider when assessing fruit quality. The skin color of abiu fruit varies with ripeness, with green being dominant in half-ripe fruit and yellow in fully ripe fruit. Color changes occurred in all fruits harvested at different maturity stages and at both storage temperatures. Half-ripe fruit retained green skin at the end of the storage period (Figure 4). The harvest maturity stage influenced the brightness, hue, and total chlorophyll content of abiu fruit skin at harvest (0 DAH). Increasingly ripe fruits had brighter skin (higher brightness) with a dominant yellow color (lower hue) (Figure 3).

Half-ripe and three-quarter ripe abiu fruits exhibited a significant increase in L* (brightness) and a decrease in hue during storage. In contrast, fully ripe fruits exhibited only a slow increase in L* and a decrease in hue (Figures 3a, 3b, 3c, 3d). The three maturity stages of abiu fruits stored at room temperature began to show similar L* values at 6 DAH

(fully ripe, 72.23; three-quarter ripe, 69.61; half-ripe, 64.98 L*) and no significant differences in hue at 9 DAH (fully ripe, 89.31; three-quarter ripe, 93.80; half-ripe, 100.19 °h). Other studies have also reported that ripe abiu had a higher brightness and lower hue than half-ripe abiu; however, by the 12th day of storage, there were no significant differences in these values (Arif et al., 2022; Sanches et al., 2017).

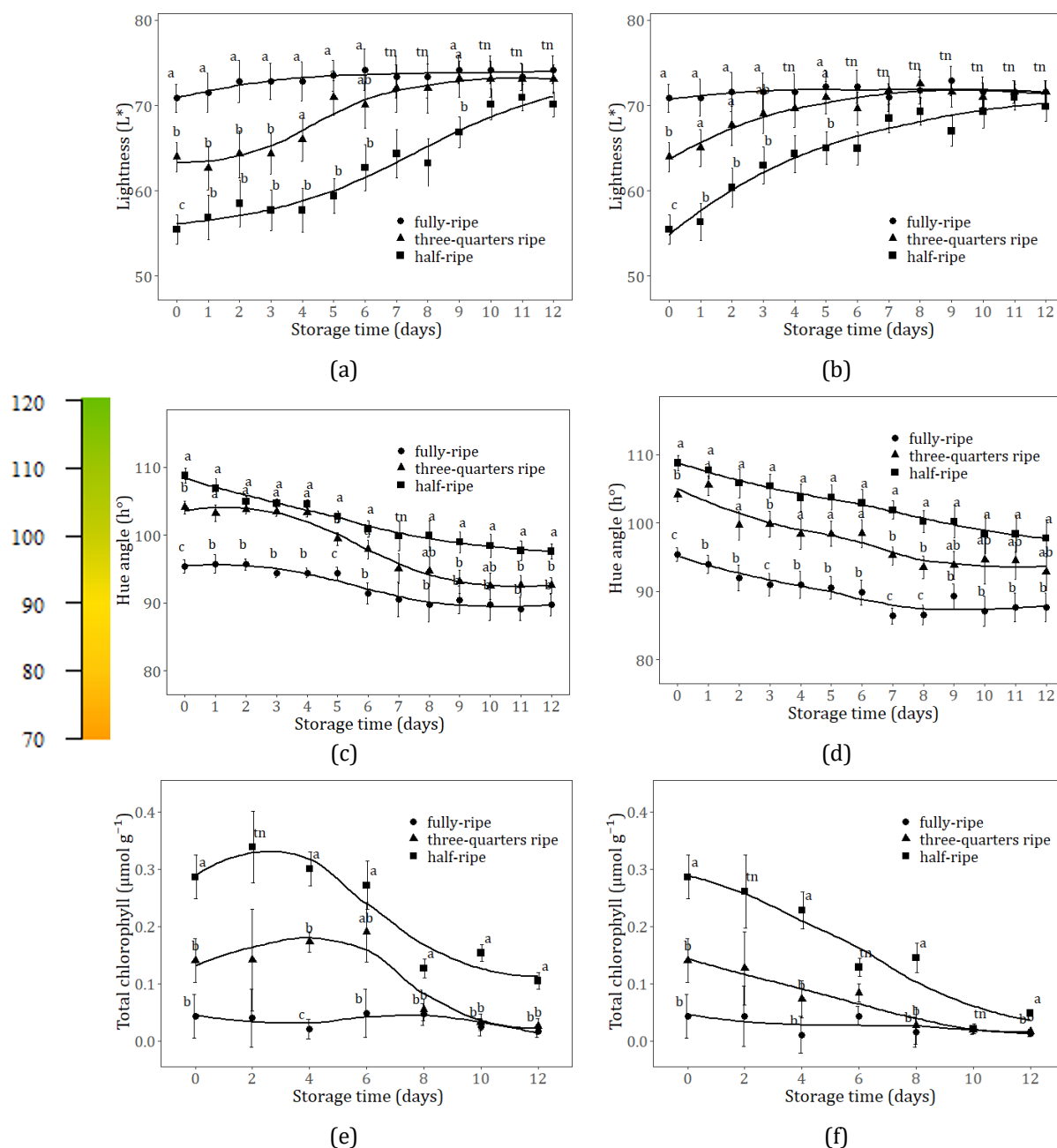


Figure 3. Changes in lightness (L*), hue angle (h°), and total chlorophyll content of abiu fruit during cold storage (a, c, e) and room-temperature storage (b, d, f). Values are presented as mean ± Standard error

The hue of abiu fruit at room temperature did not differ among the harvest maturity stages at 9 DAH, whereas it remained different at cold storage until 12 DAH. The L* of the fruit at room temperature was stable from 6 DAH, whereas it was stable in cold storage from 10 DAH. The total chlorophyll content of fruit stored under cold storage (0.105, 0.025, and 0.016 mg g⁻¹, respectively) was higher than that of fruit stored at room temperature (0.048, 0.016, and 0.013 mg g⁻¹, respectively). Based on these data, cold

storage slowed the increase in L^* (Figures 3a and 3b), decrease in hue (Figures 3c and 3d), and degradation of total chlorophyll (Figures 3e and 3f). Previous research has also shown that low temperatures cause slower changes in fruit color and chlorophyll degradation (Gill et al., 2017; Mudyantini et al., 2017). The slower color development reflects delayed chlorophyll degradation and indicates delayed overall fruit ripening.

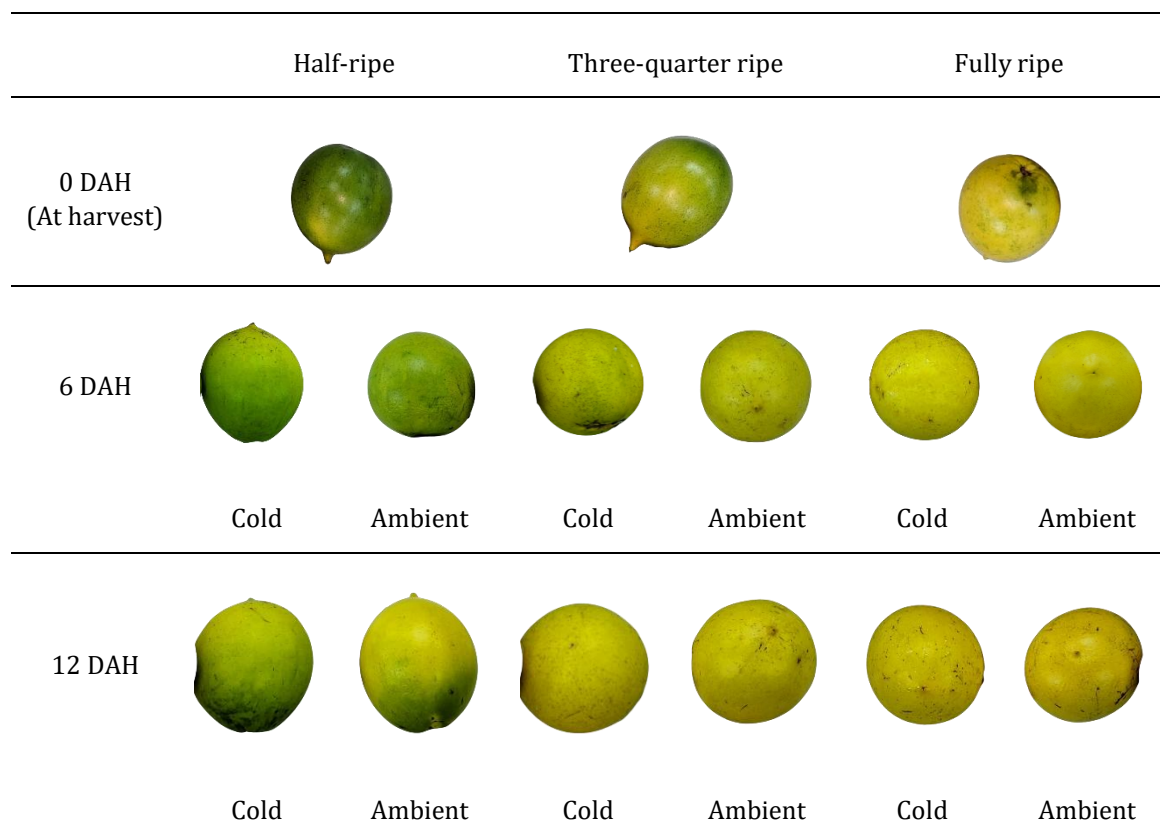


Figure 4. Changes in the color of abiu fruit during storage. DAH=days after harvest

Fruit color changes occur during the ripening process, for example, from light green to greenish-yellow (Afonso et al., 2022), or from dark/dull to bright (Williams & Benkeblia, 2018). The change from green to yellow/red is due to a decrease in chlorophyll biosynthesis and an increase in carotenoid/anthocyanin biosynthesis, which is mediated by hormonal, genetic, and environmental factors (Kapoor et al., 2022). Hue values are reported to correlate with fruit pigments, which can be used to estimate the chlorophyll content of kiwifruit (Afonso et al., 2022).

Fruit External Quality

Abiu fruit weight loss increased steadily from 1-12 DAH and was independent of the maturity stage. The weight loss at room temperature reached 6% for fully ripe (6 DAH), half-ripe (7 DAH), and three-quarter ripe (8 DAH) fruits, whereas the weight loss at all three harvest maturity stages during cold storage was only 5.29% at 12 DAH (Figures 5a, 5b). The high weight loss at room temperature was not only due to the high temperature but also to the low humidity level. The humidity at room temperature was 76.3%, whereas it was 88.1% during cold storage. Low temperatures and high humidity reduce water loss owing to low fruit respiration and transpiration rates, resulting in lower weight loss (Bovi et al., 2018; Lentzou et al., 2021); therefore, humidity-controlled packaging and cold storage are recommended. When abiu reached a weight loss of $\geq 6\%$ and a hardness of ≤ 11 N, fruit wrinkles began to appear (Arif et al., 2024).

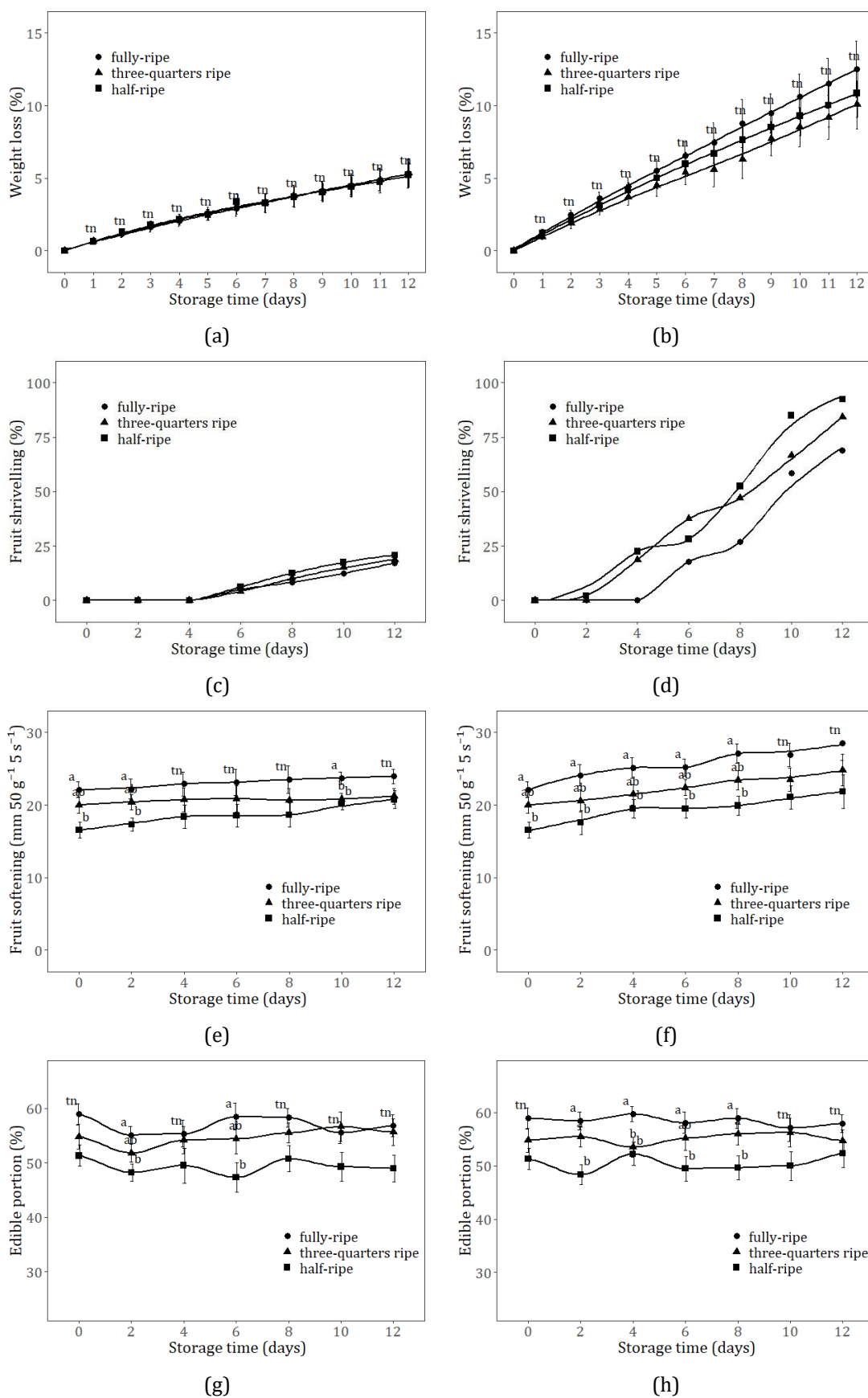


Figure 5. Changes in weight loss, shriveling, softening, and edible portion of abiu fruit during storage at: (a, c, e, g) cold and (b, d, f, h) room temperature. Values are presented as mean $\pm$ Standard error

The wrinkling level of abiu fruit stored under cold storage was much lower than that of abiu fruit stored at room temperature (Figures 5c and 5d). Abiu fruit began to wrinkle at 6 DAH when stored under cold storage and only reached 20.83% at 12 DAH. Abiu fruit stored at room temperature wrinkled more quickly (2 DAH) and reached ~50% wrinkling in half- and three-quarter ripe fruits at 8 DAH. The high degree of wrinkling in half- and three-quarter ripe fruit stored at room temperature was not consistent with the high weight loss (Figures 5a, 5b) observed in fully ripe fruit. This may be because the green skin of the fruit is not fully developed, resulting in lower structural integrity and greater susceptibility to mechanical damage. This rapid shriveling reflects the loss of turgor pressure as water moves out of the fruit tissues through transpiration, which is accelerated by the low relative humidity and high temperature (Bovi et al., 2018) as recorded in this study.

The level of harvest maturity influences abiu fruit softness. The value increased during storage and significantly differed at the end of storage (Figure 5e and 5f). Fully ripe fruit stored at room temperature was recorded as very soft ($27.10 \text{ mm } 50 \text{ g}^{-1} \text{ s}^{-1}$) starting at 8 DAH, compared with the half- and three-quarter ripe fruit. All three harvest maturity stages under cold storage had low fruit softness until 12 DAH. This is consistent with a banana study, which reported that bananas stored at room temperature exhibited a greater loss of firmness than those stored under cold conditions (Eliwa et al., 2026). Fully ripe abiu fruit is reportedly softer than half-ripe fruit (Williams & Benkeblia, 2018) because the fruit skin epidermis is thinner (Arif et al., 2022). Fruit softening results from multiple cellular processes, particularly pectin degradation mediated by pectinases such as pectate lyase and polygalacturonase, which play key roles in cell wall disassembly during ripening (Wang et al., 2018). Maintaining firmness during storage is important for handling and transportation to wider markets.

The edible portion (EP) of abiu fruit is generally influenced by harvest maturity, and no differences in EP values or changes in EP patterns were observed at the two storage temperatures (Figures 5g, 5h). During storage, fully ripe fruits tended to have a higher EP than three-quarter ripe and half-ripe fruits. This is due to differences in fruit proportions, with riper fruits having flesh with higher water content and thinner skin. This increase in the edible portion is associated with the migration of water from the peel to the pulp, driven by the increase in osmotic pressure as starch is enzymatically converted into soluble sugars during ripening (Eliwa et al., 2026).

Half-ripe and three-quarter ripe abiu fruits stored at room temperature exhibited low weight and softness losses until 8 DAH, whereas fully ripe abiu fruits exhibited high weight and softness losses starting at 6 DAH. Abiu fruit stored under cold storage exhibited low weight, softness, and wrinkle levels throughout the storage period. Weight loss, softness, and wrinkle levels are interrelated attributes of fruit quality that influence consumer decisions.

Fruit Internal Quality

The chemical contents commonly assessed as fruit quality attributes are TSS and TA. The TSS of abiu fruit (0 DAH) was influenced by the harvest maturity stage (from fully ripe: 13.36, 12.27, and 11.12 °Brix, respectively) and increased during storage (Figure 6a, 6b). The TSS of abiu fruit (0 DAH) was not affected by the harvest maturity stage (from fully ripe: 0.074, 0.078, 0.086%, respectively) and decreased during storage (Figure 6c and 6d). Titratable acidity (TA) decreases because the fruit requires organic acids during its metabolic processes, whereas the TSS value increases because starch is degraded and converted into TSS components (Basak et al., 2022). The increase in TSS and decrease in TA in abiu fruit during storage were consistent with the results of previous studies (Arif et al., 2022; Sanches et al., 2017).

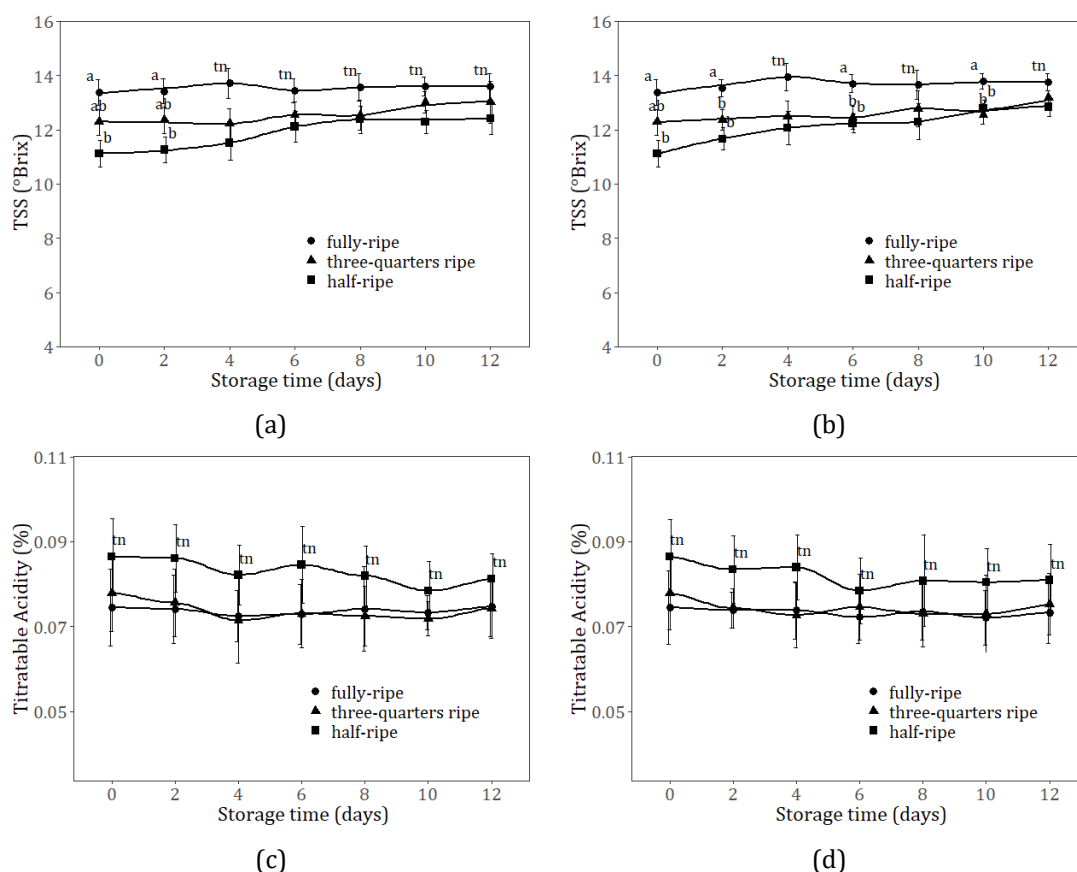


Figure 6. Total soluble solids (TSS) and titratable acidity (TA) of abiu fruit during storage at different temperatures: (a) and (c) cold; (b) and (d) room temperature. Values are presented as mean $\pm$ Standard error

Cold storage slowed the increase in TSS and the decrease in TA of abiu fruit compared to storage at room temperature (Figure 6). Previous research has also shown that TSS and TA in mango and banana fruits exhibit slower changes when stored at low temperatures (Eliwa et al., 2026; Gill et al., 2017). This is because metabolic processes (respiration, starch degradation, and sugar accumulation) occur slowly, resulting in more gradual changes in TSS and TA and allowing the characteristic flavor balance of abiu fruit to be maintained for a longer storage period.

Flavor, particularly as reflected by the TSS/TA ratio, is a major determinant of consumer acceptance and encourages repeat purchases (Brückner, 2008). Consumer preferences are influenced by both product attributes, with physical attributes being the dominant factor, and consumer attitudes, including perceptions of freshness, taste, and price. The presence of imported fruits does not significantly affect consumer preferences, suggesting that improving the quality of local fruits is essential to enhance their competitiveness (Maharani & Putri, 2026).

CONCLUSIONS

Abiu harvested (0 DAH) at the fully ripe and three-quarter ripe stages had better quality (based on color, softness, EP, TSS, and TA) than half-ripe fruit. Peak CO_2 production during room temperature storage occurred sequentially in fully ripe (6 DAH), three-quarter ripe (7 DAH), and half-ripe (9 DAH). Cold storage delayed peak CO_2 production by two days. Abiu fruit stored at room temperature maintained good quality (in terms of color, EP, TSS, and TA) until 6 DAH for fully ripe fruit and until 8 DAH for half-ripe and three-quarter ripe fruit. Abiu fruit at all three harvest maturity stages stored under cold storage until 10-12 DAH still had good fruit quality, with the best quality being observed in fully ripe, followed by three-quarter ripe, and then half-ripe fruit.

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