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Physicochemical and micro-morphological on banana peel splitting

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Abstract Peel cracking in barangan merah bananas was associated mainly with biochemical and structural changes rather than physical dimensional alterations. Bananas exhibiting peel splitting showed significant differences in pH and total soluble solids (TSS) compared with non-splitting fruit, particularly at the sixth storage period, indicating advanced biochemical changes related to ripening and deterioration. Splitting fruit generally exhibited altered acidity and increased soluble solids, reflecting intensified metabolic activity. Micro-morphological observations revealed clear structural differences between splitting and non-splitting peels, suggesting tissue disruption and cellular degradation in cracked fruit. In contrast, peel splitting did not significantly affect physical dimensions, including peel length and width, indicating that cracking was not driven by external expansion or growth-related stress. Weight loss patterns were not markedly different between splitting and non-splitting bananas, suggesting that moisture loss was not the primary cause of peel cracking. Overall, peel splitting in barangan merah bananas reflects internal biochemical deterioration and micro-structural damage rather than changes in physical size, and may serve as a visible indicator of reduced fruit quality and shortened shelf life during storage.

Keywords: Banana splitting, Barangan merah banana, Cracking, Dimension, Microscopy

Introduction

Banana is one of the climatic fruits that will ripen (ripe) even though it has been picked from the tree. Ripe bananas are characterized by their yellow skin. Ripe bananas can only last for a few days before rotting, so the shelf life of ripe bananas is relatively short. To extend the shelf life of bananas, ripe bananas are usually processed into processed products such as banana sales (Macedo *et al*., 2020). The utilization of bananas for processed products is not only for ripe bananas but also for mature bananas. Mature bananas are usually made into chips or processed semi-finished food, namely banana flour (Jumras *et al*., 2020; Kumar *et al*., 2019; Paramasivam *et al*., 2022). Banana flour is an ingredient in

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manufacturing food products such as cookies (Agama-Acevedo *et al*., 2012; Arise *et al*., 2021; Hasan *et al*., 2020; Olawoye *et al*., 2023), cakes (Souza *et al*., 2018) and sponge cakes (Segundo *et al*., 2017). Efforts to extend the shelf life of bananas require proper post-harvest handling. One of the post-harvest problems of banana fruit is peel splitting. Peel splitting is a physiological damage in bananas—a longitudinal crack marks peel splitting. Peel splitting causes losses to farmers because banana fruits that experience peel splitting cannot be marketed. Of the total banana production of barangan in one plantation in Lunjuk village, Seluma district, peel splitting was found to be 20%. Peel splitting can occur during fruit ripening. Peel splitting is characterized by longitudinal splits in the skin, usually starting from the proximal (tip) to the pedicel (base). The split usually divides the peel into unequal parts and eventually opens the pulp into a wide split (Dadzie and Orchard, 1997). Peel splitting was caused during maturation. It increased glucose content due to the hydrolysis of starch. High glucose (hypertonic) in the pulp of the banana was triggered by different peel and pulp stress, so the cell wall swelled and induced a crack in the banana peel (Khanal *et al*., 2023).

Studies on splitting have previously been conducted on pomegranates (Fraschetti *et al*., 2023; Mokhtarzadeh and Shahsavar, 2020), citrus (Jiao *et al*., 2022), and murcotte tangerine (Mohsen and Ibrahim, 2021). Wo *et al*. (2005) mentioned that peel and pulp splitting in banana mas occurred at week 7 after flowering, and the amount of splitting increased with increasing maturity, namely weeks 8 and 9 (Brat *et al*., 2016). Brat *et al*. (2016) mentioned that peel splitting in cavendish bananas is related to the flow of water from pulp to peel at high relative humidity. The results also showed that the sugar content in the pulp was higher than in the peel.

There has not been much research on peel splitting in banana fruit. Therefore, there is a need for a study on peel splitting that analyses bananas' physical and chemical properties. To determine the differences between bananas that experience peel splitting and bananas that do not experience peel splitting. After analyzing the physical and chemical properties of banana peel splitting and non-splitting, efforts can be made to reduce the problem of peel splitting in bananas. In addition, fruits that experience peel splitting can be optimally utilized for processed products of the physical and chemical properties they contain. Chemical properties it contains. This reduces the losses caused by peel splitting, such as splitting, e.g., economic losses because splitting bananas are considered poor quality.

The objective of this study was to determine the differences in physical and chemical properties between barangan merah bananas that experience peel splitting and those that do not, as a basis for understanding the occurrence of peel splitting, reducing associated postharvest and economic losses, and supporting the optimal utilization of splitting bananas for processed products.

Materials and methods

Tools and materials

The tools used in this research were the dryer tool YSD-UNIB18, pH meter, oven, desiccator, analytical scales, furnace, and desiccator and analytical scales. The material used in this research was banana fruit barangan field, obtained from Lunjuk village, Seluma Regency, Bengkulu, Indonesia.

Preparation of materials

The bananas were 70-80 days old after the banana heart appeared. The bananas observed were splitting and non-splitting bananas. Bananas from the field were handled with cardboard packaging and stacked in a maximum of three piles. Lastly, the bananas were stored and observed.

Dimensional analysis

Physical observations of bananas in the form of length and width of the banana fruit and the length, width, and depth of the split in the banana using a digital caliper were done (Kamble *et al*., 2021). Observations were made every day. Dimensional changes were measured by the difference between the initial and final dimensions and divided by the initial dimension.

Total soluble solids

Total Soluble solids (TSS) were obtained using a hand refractometer (Cho and Koseki, 2021). It was tested on day six.

pH

pH analysis using a pH meter (Cho and Koseki, 2021). pH was analyzed on the last day of storage (6^{th}).

Weight loss

Weight loss is measured by the difference between the material's initial and final weights. Weight loss observations were made daily (every 24 hours). The weight loss equation refers to (Pah *et al*., 2020).

$$\% \, Weight \; loss = \frac{W - Wa}{W} \, x \, 100$$

W: weight loss at the beginning of the storage
Wa: weight loss at the end of the storage

Analysis of morphology

Scanning Electron Microscope (SEM) analysis was carried out on banana peel and flesh that experienced splitting and not. In the first stage, the peel and pulp were separated. Then, the peel and pulp were sliced with a thickness of ±1cm. The whole sample was then dried using the dryer tool YSD-UNIB18 for five days until the moisture content was <20%. The dried samples of peel and pulp were then stored in ziplock plastic. The samples were then analyzed using SEM JOEL JSM-6510LA with JEOL JEC-3000FC Auto Fine Coater and a 5 mm microscope lens with 5000X magnification. The samples to be tested were prepared first by attaching the samples to carbon tape on top of the specimen holder. Next, the Au/Pt coating stage is done by inserting the sample into the auto coater and waiting until the vacuum coater machine reaches a pressure of <5 Pa. Start the coater for at least 120 seconds at 20 mA (according to sample needs). The final step is to insert the sample into the SEM and vacuum it for 1 minute. Then, the sample is shot with an electron beam with the spot size needed. Then, the sample surface can be observed with small and large magnification.

Statistical analysis

The obtained data were analysed using the independent sample t test. The test was used to determine the difference between spliiting and non-splitting bananas.

Results

Length change

The length change trends in bananas over time (6^{th}) is illustrated in Figure 1. Overall, there were upward trends in banana Another Banana splitting and non-splitting were found to be the same trends. The length change in banana splitting was not significantly affected for banana non-splitting.

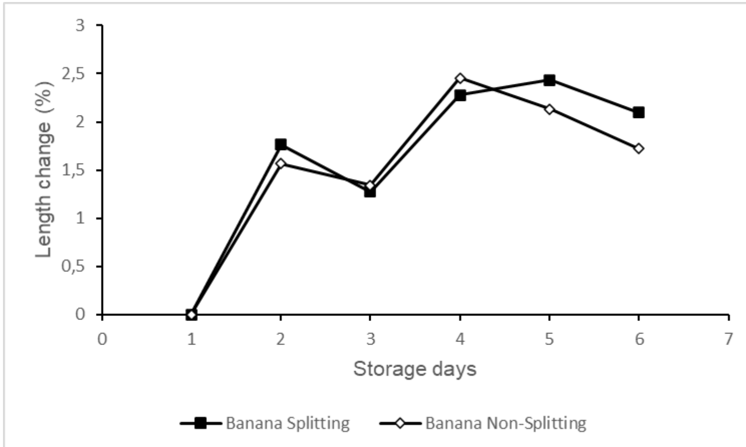

Figure 1. Length change on banana peel splitting and non-splitting

Width change

The width changes in banana splitting and non-splitting is shown in Figure 1. Overall, there have been rising trends in both (Figure 2). Another appealing point is that banana splitting was the most remarkable width change during the days. Splitting on bananas did not have a significant effect on width change. To begin with, the width changes on banana splitting started at approximately 4%, fluctuated gradually from day 2nd to 3rd, and then increased significantly at just under 8% on the 4th day. Furthermore, it decreased slightly, just above 7%. Regarding banana non-splitting, there was a fluctuation until day 3rd, which rose gradually to roughly 4% on day 5th, then went down considerably to approximately 3% at the end of storage (6th).

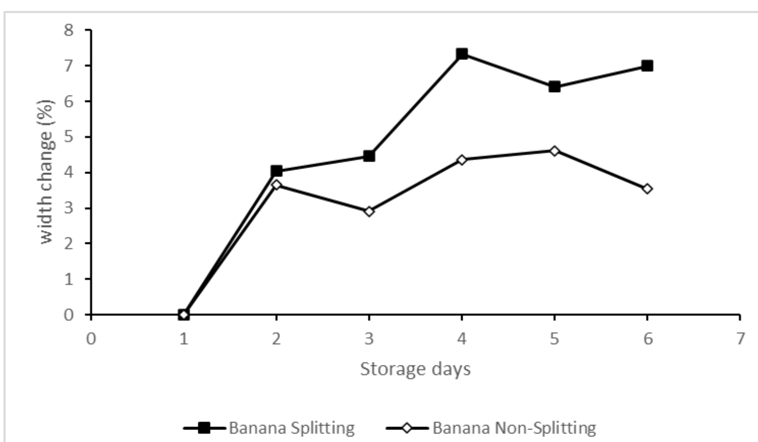

Figure 2. Width changes on banana peel splitting and non-splitting

Crack zone change

The crack zones on a banana peel, such as length, width, and depth split are shown in Figure 3. Overall, there were upward trends in all parameters. Crack zone change occurred during storage for 6 days. Depth and width change increased significantly, just above 12% on the sixth day.

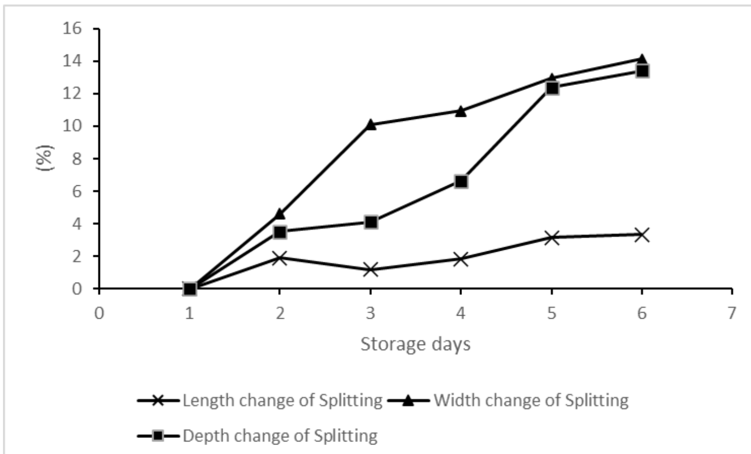

Figure 3. Crack zone changes on banana peel splitting

Weight loss

The graph provides information regarding weight change in banana (Figure 4). There were fluctuating trends in banana splitting and banana non-splitting. Another interesting point is that the weight change on the fourth day was the most significant factor in banana splitting. On the other hand, the weight change of bananas non-splitting on the fourth day was the lowest. Overall, fluctuating trends were observed in both split and non-split bananas. Notably, the fourth day showed the highest weight change in split bananas, whereas the weight change in non-split bananas was the lowest on the same day.

pH on banana peel splitting and non-splitting

The flesh of banana fruit had an acidity related to total soluble solids (TSS). The ratio between TSS and acidity correlated with taste.

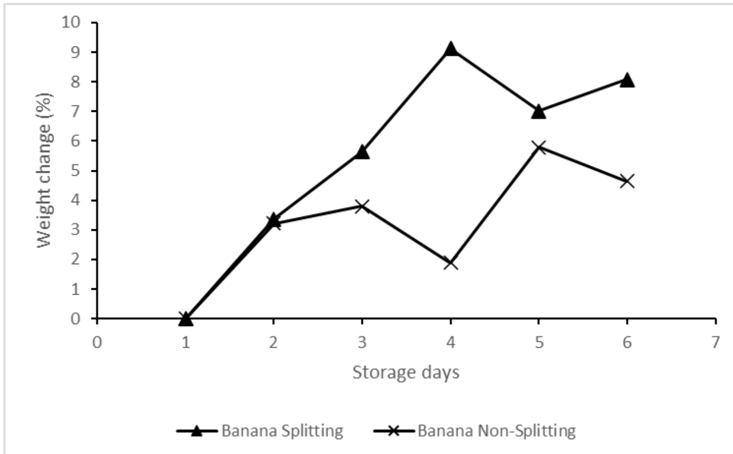

Figure 4. Weight loss on banana peel splitting and non-splitting

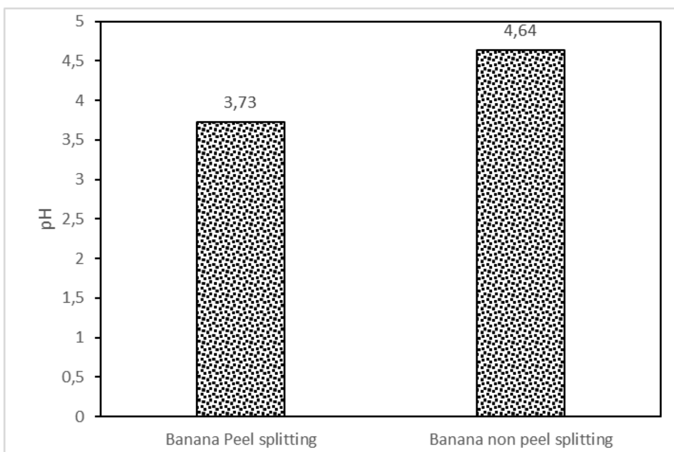

Figure 5. pH on banana peel splitting and non-splitting

Total soluble solid

Total soluble solids (TSS) represented the dissolved solids, mainly sugars. Additionally, TSS also contains organic acids, proteins, and minerals. The soluble sugars rose in mature fruit. TSS in banana non-peel splitting is greater than banana peel splitting because of a factor related to it (Figure 6).

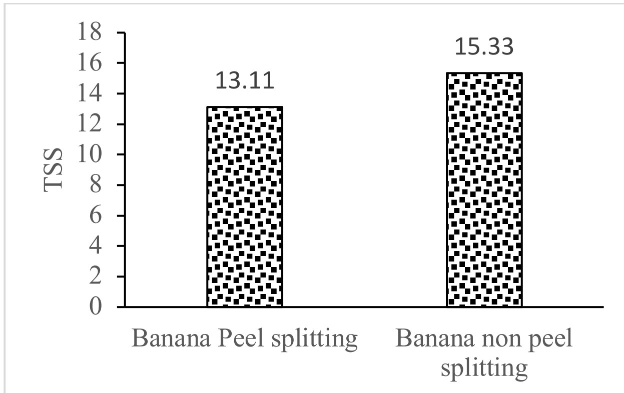

Figure 6. TSS on banana peel splitting and non-peel splitting

Micro-morphology on banana peel splitting and non-splitting

Splitting occurs on a banana peel that cracked a longitudinally from base to tip fruit, splitting eventuated on the corner or curved side and flat of the peeled banana. Cracks on the banana peel exhibited brown and black (Figure 7).

Figure 7. Banana Peel Splitting looks crack longitudinal

SEM determined the shape and size of starch granules, surface morphology, and structural integrity. The peel splitting in bananas; the epidermal cells were cracked (Figure 8). The rupture of epidermal cells became several parts. This matter was marked with red colors (Figure 8a). On the contrary, the banana non-peel-splitting epidermal cell appeared intact and round. There was no crack on banana epidermal cells (Figure 8b).

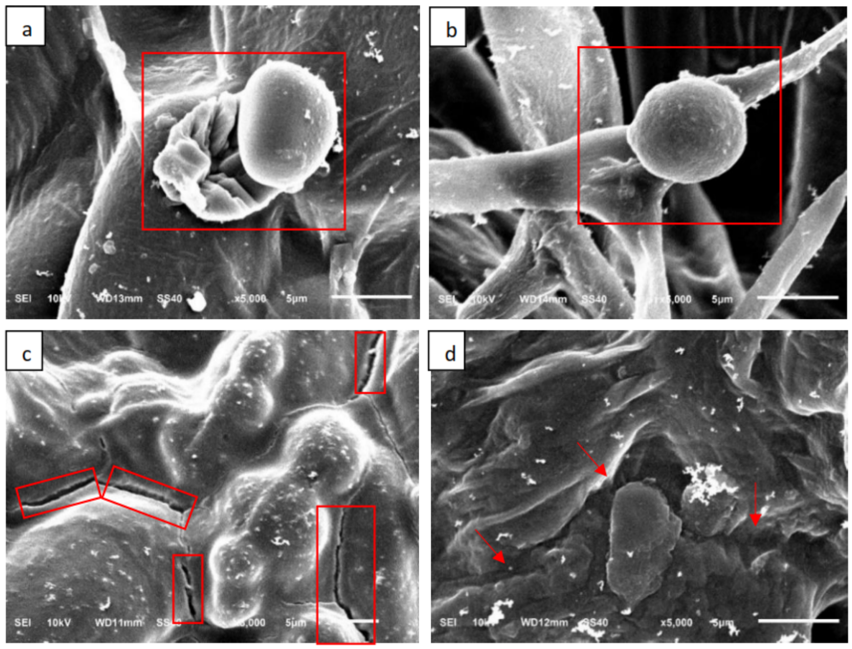

Figure 8. Banana peel splitting (a), banana non-peel splitting (b), Flesh, banana peel splitting (c), Flesh, banana non-peel splitting (x 5000 5 µm) (d)

Discussion

On the 5th day of storage, there was a slow increase in length change, which decreased gradually by approximately 2% on the 6th day of banana splitting. Lastly, the length change was more significant for the splitting banana than the non-splitting banana on the 5th and 6th day. According to Sudjatha and Wisaniyasa (2017), mature climacteric fruits will experience an increase in respiration rate to the maximum level. When the maturity is corrected, there would be irreversible ripening stimuli. Damage in the form of peel splitting affected changes in fruit length that can accelerate fruit ripening so that decay will occur faster.

The change in width of the splitting banana was greater than that of the non-splitting banana. This difference in width change is due to the cracking of the banana peel, which increased the respiration rate and triggers faster metabolic processes. This is also caused the splitting banana to decay faster. Another possibility is that there was an imbalance inside, causing expansion, which resulted in a change in the dimensions and shape of the banana (Jiao *et al*., 2022). In addition, the respiration process on climacteric fruits may cause the crack zone change. Split on a banana peel is lead absorption rainwater before harvest (Wo *et al*., 2005).

Splitting results in the pulp being directly exposed to the environment due to the split and exposed condition of the skin. This condition makes the pulp susceptible to damage, such as mold growth, insect attacks, and other microorganisms. Another condition is reducing water content in the pulp because the split skin makes it easier for water to evaporate into the environment, so the pulp looks dry. Splitting exposed the pulp to the environment due to the compromised skin condition. This exposure made the pulp more vulnerable to damage, such as mold growth, insect infestation, and other microbial activities. Additionally, the reduced water content in the pulp is attributed to increased evaporation caused by the split skin, leading to a visibly dry appearance.

Banana peel splitting had a lower pH than banana non-splitting, which relates to the observation from (Jayasekara *et al*., 2021). TSS peel splitting on *Citrus sinensis* contains acidity such as ascorbic acid; it was higher on *C. sinensis* (splitting) than (non-splitting). A higher ascorbic acid showed a lower pH (Jayasekara *et al*., 2021).

Banana non-splitting was protected by intact peel, so the peel protects from external conditions and maintains regular metabolism, including sugar establishment from hydrolysis starch during the maturation process. On the contrary, banana splitting involves pulp exposure, increasing the risk of external environments such as air and microorganisms. Bananas uncovered were more susceptible to microbial growth like mold or bacteria that consumed sugars, reducing TSS. Moreover, split bananas tended to ripen quickly or unevenly, resulting in suboptimal sugar development. Pomegranate fruit juice from (non-peel splitting) had TSS higher than pomegranate fruit juice (peel splitting) because of potassium contents(Mokhtarzadeh and Shahsavar, 2020), making it similar to the TSS on murrcot tangerine fruit (Mohsen and Ibrahim, 2021). Fruit splitting happened on *Citrus sinensis*; it had TSS, which was lower than TSS on control (Jayasekara *et al*., 2021).

Wo *et al*. (2005) stated the split on the banana peel had darkened and moldy. Splitting was antedated by radial rupture from the inner peel, which continued outwards of the peel. Moreover, there were a lot of cracks on the banana in the corner of the peel (Khanal *et al*., 2023). In addition, the splitting of mature and ripe lemon fruit occurred, which marked visible cracks on the peel (Jayasekara *et al*., 2021). Subsequently, these observations coincide with Li and Chen (2017) on *Citrus lemon,* that peel splitting occurred during a long dry season and then heavy rain, so the fruit peel absorbed reserve water and swelled, and lastly, splitting happened. Another possibility is the local stress caused by the development inside the fruit, which results in an imbalance inside and promotes longitudinal cracking (Jiao *et al*., 2022).

According to Brat *et al*. (2016), the bananas undergoing peel splitting looked like a break zone inside the epidermis. Instead, it did not happen on bananas non-peel splitting, and the epidermis appeared undamaged. The fruit splitting happened on lychee, lemon, pomegranate, apples (Butani *et al*., 2019), and sweet cherries (Yildirim and Koyuncu, 2010). Furthermore, gibberellic acid mitigated this fruit's splitting, which increased the elasticity and glucose of cell walls (Choi *et al*., 2002). In addition, potassium prevented fruit splitting with the development of thicker peeled fruit (Ali *et al*., 2000). Thick fruit peel may mitigate the risk of breaking on the peel fruits.

Based on the result, the split on the barangan merah banana had a significant effect on pH and TSS in the sixth storage. There was a difference between banana peel splitting and non-splitting on morphological analysis. On the contrary, splitting on barangan merah did not impact dimensions (length, width change).

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Conflicts of interest

The authors declare no conflict of interest.

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