Inornatus: Biology Education Journal
Volume 4, Issue 2 (2024): 123 – 131
DOI: 10.30862/inornatus.v4i2.682

Alterations in the sucrose content and texture of *Carica papaya* var. California L. and *Musa paradisiaca* var. formantipyca L. as ripen

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Submitted: 29-07-2024

Accepted: 30-08-2024

Published: 12-10-2024

Abstract: Changes in texture and sucrose content in California papaya and kepok bananas after harvest due to metabolic processes can reduce the quality of the fruit. This research investigated the changes in sucrose content and texture during the maturation process of California papayas and kepok bananas. The observed parameters included physical properties, such as texture variations and sucrose levels in the fruit. The research followed a qualitative approach. The research results are described descriptively. This study showed a change in the texture of the kepok banana and California papaya in the ripening process. Changes in the texture of kepok bananas decreased from 3.66 kg/cm on day 2 to day 12 after harvesting from 3.66 kg/cm to 0.56 kg/cm. California papayas from 3.63 to 1.36 kg/cm2. California papayas from 3.63 to 1.36 kg/cm2. The highest sucrose content in the ripening process occurred in kepok bananas and California papayas, respectively, at 0.45° Brix on day 12 and 11.38° Brix on day 10.

Keywords: Ripening process, sucrose content, texture changes

Abstrak: Perubahan tekstur dan kandungan sukrosa pada pepaya California dan pisang kepok setelah panen akibat proses metabolisme dapat mengurangi kualitas buah. Penelitian ini bertujuan untuk mengetahui perubahan kadar sukrosa dan tekstur selama proses pematangan buah pepaya California dan pisang kepok. Parameter yang diamati adalah sifat fisik termasuk perubahan tekstur dan kandungan sukrosa buah. Jenis penelitian ini adalah kualitatif. Hasil penelitian dijelaskan secara deskriptif. Penelitian ini menunjukkan adanya perubahan tekstur pada pisang kepok dan pepaya California dalam proses pematangan. Perubahan tekstur pada pisang kepok menurun dari hari ke 2 – 12, setelah panen dari 3.66 kg/cm menurun ke 0.56 kg/cm. Pada pepaya California, dari 3.63 menurun ke 1.36 kg/cm². Kandungan sukrosa tertinggi dalam proses pematangan terjadi pada pisang kepok dan pepaya California, masing-masing pada 0.45° Brix pada hari ke-12 dan 11.38° Brix pada hari ke-10.

Kata kunci: Proses pematangan, kandungan sukrosa, perubahan tekstur

INTRODUCTION

Fruit is one of the essential nutrients needed by the body daily. The nutrient values of bananas are crucial for meeting the daily dietary needs of individuals across various age groups. Bananas are rich in essential nutrients, including dietary fiber, vitamins, and minerals, which contribute significantly to health and well-being. For instance, bananas are known for their high content of dietary fiber, particularly resistant starch, which has been associated with various health benefits such as improved gut health and reduced risk of chronic diseases

(Khoza & Dlamini, 2021; Tuárez-García et al., 2023). The vitamins, minerals, antioxidants, and fiber in fruit play an important role in the body's metabolic processes (Suparinto, 2013). Indonesians commonly consume bananas and papayas. Consuming two bananas a day is enough to meet iron intake for anemic patients. Bananas are the best food because they contain vitamins (Rad et al., 2021).

Banana plants are also frequently utilized to supplement human needs. Every part of this plant has numerous benefits, from the trunk to the fruit. Bananas are an excellent source of vitamins and minerals, including potassium, vitamin C, and vitamin B6, which play vital roles in bodily functions. Potassium is crucial for maintaining healthy blood pressure levels and proper muscle function, while vitamin C is important for immune function and skin health (Tuárez-García et al., 2023). The antioxidant properties of bananas, attributed to their phenolic compounds, further enhance their nutritional profile, providing protective effects against oxidative stress (Amarasinghe et al., 2021). In addition to their antioxidant properties, bananas are rich in essential nutrients, including minerals such as magnesium, potassium, and phosphorus, as well as vitamins like vitamin C and B complex. A study on the biochemical and nutritional characteristics of various banana cultivars revealed that bananas are a significant source of vitamin C, with levels varying among cultivars (Malikongwa et al., 2022). In addition to bananas, papaya is another high-value fruit that is rich in fiber. Like the banana plant, almost every part of the papaya plant is useful, including leaves, flowers, and fruit. The fruit is known for its distinctive thick, soft flesh, which ranges in color from red to yellow or orange. Its sweet flavor and high water content make it a refreshing choice when eaten (Ahmad, 2013).

In general, bananas and papayas are consumed when they are fully ripe. However, these two fruits can also be harvested before they reach full ripeness. The process of taking fruit from the tree and making it fit for consumption is called the fruit ripening process. This process is a series of changes that make the fruit immature until it becomes perfectly ripe and ready to eat (Ahmad, 2013). Throughout this process, the fruit will undergo various changes, including alterations in texture and sucrose levels. The tannin compounds in immature fruit cause a bitter taste, but this taste is lost during the ripening process due to decreased tannin levels when the fruit is ripe (Rahayu & Duryaman, 2016). Additionally, the change in fruit aroma is due to the production of complex compounds from the breakdown of volatile compounds and some essential oils. Pectin and cellulose compounds greatly determine the texture of the fruit. In the ripening process, these two compounds decrease in number, making the fruit become softer. The amount of pectin increases and the amount of insoluble protopectin decreases. The cellulose content in bananas at the time of harvest is approximately 2-3%, and this percentage decreases as the fruit ripens. This phenomenon can be attributed to the biochemical changes that occur during the ripening process, particularly the degradation of cell wall components, including cellulose. Research indicates that as

bananas ripen, there is a significant reduction in starch content, which is closely linked to the softening of the fruit and the decrease in firmness associated with ripening (Xiao et al., 2017).

The conversion of starch into simple sugars like sucrose, glucose, and fructose gives ripe fruit its sweet flavor (Aprea et al., 2017; Hu et al., 2016; Smith et al., 2022). This is an indicator of the amount of sucrose present in the fruit. Sweet fruit flesh will contain a lot of sucrose, while fruit flesh that is not sweet shows little sucrose content. The standard of sucrose in sweet fruit is around 100 Birx (Bussières et al., 2011). The two fruits that will be studied, namely the kepok banana and California papaya, are included in climacteric fruits with distinctive signs at a certain degree of maturity at harvest. Climacteric fruit can be harvested when conditions are not fully ripe, as the fruit will continue to ripen and ripen perfectly after being harvested and stored at room temperature. The level of CO_2 produced at the end of fruit ripening is one of the characteristics of climacteric fruit (Chen et al., 2018; Jia et al., 2017; Ming-chun et al., 2015).

During fruit ripening, the biochemical process occurs through the action of the hormone ethylene. This hormone has a significant impact on the shelf life. Ethylene can damage the color of the fruit, causing it to rot quickly. This results in a decrease in the quality of the fruit before it reaches the marketing location, so it is necessary to inhibit the process of damage to the fruit. The decrease in fruit quality can be seen from changes in texture and the amount of sucrose content in the fruit, so proper handling and a good understanding of the physiological processes after harvest are needed. Consequently, this research examines the changes in texture and sucrose levels during the ripening process of California papayas and kepok bananas after harvest.

METHOD

Between August and October 2021, the research was conducted at the Post-Harvest Processing Laboratory of Politeknik Negeri Lampung. This study uses a portable refractometer, toca color finder, fruit hardness tester, knife, filter, spoon, tissue, camera, 18 Musa paradisiaca var. Formantipyca (kepok bananas), and 18 Carica papaya var. California, which was ripe and ready for harvest, was utilized. Texture and sucrose content measurements were taken every two days, from day two to day twelve after harvest.

Texture testing

This procedure uses a fruit hardness tester. The tool functions by inserting its tip into the fruit, and the hardness level is displayed on the device. The test was conducted over 12 days with 6 trials. Measurements were taken from three different parts of the fruit: the base, the middle, and the tip.

Testing for sucrose content

This test was carried out with a portable refractometer with 6 trials in a 12-day period. esting the sucrose content begins with cutting the fruit, then grating and filtering. The water

produced from the filter is dripped into the refractometer. Results can be seen on the underside of the tool in bright locations. The samples taken included the tip, middle, and base of the fruit, with sucrose content measured in degrees (°) Brix.

RESULTS AND DISCUSSION

Changes in the texture of Californian papayas and kepok bananas

The variations in texture of Californian papayas and kepok bananas are displayed in Tables 1 and 2.

Table 1. The texture of Californian papaya fruit as ripen

Part of Fruits	The texture of Californian papaya (kg/cm²) as ripen (day of-)					
	2	**4**	**6**	**8**	**10**	**12**
Tip of the fruit	3.7	3.6	2.7	1.85	1.5	1.5
Middle	3.65	3.45	2.4	1.65	1.55	1.3
Base	3.55	3.5	2.2	1.7	1.6	1.3
Average	3.63	3.51	2.41	1.75	1.55	1.36

Table 2. The texture of the kepok banana fruit as ripen

Part of fruits	The texture of kepok banana (kg/cm²) as ripen (day of-)					
	2	**4**	**6**	**8**	**10**	**12**
Tip of the fruit	3.8	3.55	1.35	0.85	0.6	0.45
Middle	3.55	3.4	1.65	0.8	0.55	0.5
Base	3.7	3.5	2	1.1	0.8	0.75
Average	3.68	3.43	1.66	0.91	0.65	0.56

Tables 1 and 2 illustrate the texture changes in California papayas and kepok bananas during the ripening process. For both fruits, there is a positive correlation between ripening time and texture softening; the longer the ripening period, the softer the texture. However, the decline in texture is more pronounced in kepok bananas compared than California papayas. By day 12, the texture value of the papaya fruit remains higher than that of the kepok banana, indicating a slower rate of softening in the papaya.

Sucrose of papaya and kepok banana

Tables 3 and 4 illustrate the sucrose content of Californian papayas and kepok bananas.

Table 3. Changes in the sucrose content of Californian papaya fruit as ripen

Part of fruits	Sucrose (0) brix (day of-)					
	2	4	6	8	10	12
Tip of the fruit	9.3	9.50	10.15	10.54	11.25	11.35
Middle	9.5	9.76	10.13	10.31	11.20	11.27
Base	9.4	9.55	10.5	10.27	11.7	11.18
Average	9.4	9.6	10.24	10.37	11.38	11.3

Data on the sucrose content of California papayas are presented in Table 3. The sucrose content has been present since day 2 and increases with increasing ripening time.

Table 4. Changes in the sucrose content of kapok bananas as ripen

Part of fruits	Sucrose (0) brix (day of-)					
	2	**4**	**6**	**8**	**10**	**12**
Tip of the fruit	0	0	10.25	10.5	10.60	10.63
Middle	0	0	10.20	10.22	10.55	10.50
Base	0	0	10.5	10.5	10.15	10.23
Average	0	0	10.31	10.42	10.43	10.45

Table 4 shows the sucrose levels in kepok bananas at different stages of ripening. The sucrose content began to increase on the 6th day of ripening, and it increased dramatically until the 12th day.

The texture and taste of fruit are key factors that attract people when choosing fruit for consumption. These two things play an important role in determining the quality of the fruit. A texture that is not too soft and a sweet taste is a top priority for consumers. The results of the research that has been carried out show that there is a change in the texture of the kepok banana and California papaya that occurs during ripening. The texture of the fruit changes as storage time increases, becoming softer the longer it is kept. Extended storage can cause the fruit to lose its freshness and visual appeal, eventually leading to spoilage. This process is driven by enzymatic breakdown, primarily involving esterase and glycanase enzymes (Bussières et al., 2011).

The decrease in fruit texture is related to the structure of the middle lamella and cell walls that undergo pectin depolymerization. In bananas, ripening causes an increase in water-soluble pectin and a decrease in acid-soluble pectin. This is due to galactose and galacturonic acid stimulation, which have increased to become the main monosaccharides in pectin polysaccharides (Sudjatha & Wisaniyasa, 2017). According to Andriani et al. (2018), the soft structure is caused by damage to cell shape, cell wall composition, and intracellular components in the fruit, as well as biochemical processes that include the degradation of water-insoluble pectin become dissolved due to a decrease in cohesive forces between cell walls.

Pectin plays a role in maintaining cell rigidity, but when it is converted into sugar and acid groups by specific enzymes, this leads to a softening of the fruit's texture. In climacteric fruits such as bananas and papayas, an increase in respiration rate occurs as they approach the climacteric peak, which accelerates transpiration from the fruit to the environment. This process takes place during ripening, leading to a reduction in papaya fruit weight, as well as damage and a decrease in fruit quality (Gardjito & Swasti, 2018). Additionally, both pectin and starch levels decrease during fruit ripening.

Starch is a type of carbohydrate and a condensation polymer composed of hundreds of glucose monomers that chemically react with water. The main components of starch are amylose and amylopectin (Sudjatha & Wisaniyasa, 2017). Starch is one of the most abundant carbohydrate groups in bananas. The higher the starch content, the firmer the banana's texture will be, and vice versa (Musita, 2012). The hydrolysis of starch produces maltose, and further hydrolysis of maltose yields the monosaccharide D-glucose. Water content also affects the texture of the fruit. During fruit ripening, respiration continues, producing CO_2 and H_2O. The increased water content leads to a decrease in fruit texture. Additionally, variations in osmotic pressure result in water moving from the fruit skin to the fruit flesh (Widyasanti et al., 2019).

Research on the IPB9 variety of papaya shows that the fruit becomes sweeter as it ripens, a change attributed to the increased sucrose content in the ripe fruit (Arifiya et al., 2017). Similarly, Larasati et al. (2019) found that an increase in sucrose content accelerates the ripening process in bananas. As bananas ripen, the starch content decreases due to hydrolysis, converting the starch into simpler sugars. Kusumiyati et al. (2018) further explained that during storage, fruit degrades carbohydrates into simple sugars, whereas in unripe fruit, carbohydrates are primarily stored in the form of starch. These studies collectively highlight the critical role of carbohydrate transformation in the ripening process of fruits like papayas and bananas.

During the fruit ripening process, one of the key indicators is an increase in the sweetness of the fruit, which reflects a rise in sugar content within the fruit flesh (Dwivany et al., 2021). Sucrose, a disaccharide composed of glucose and fructose, is integral to the sweetness of fruits and serves as a primary energy source in plants. The formation of sucrose occurs through a glycosidic bond between its monosaccharide units, which is crucial for energy storage and metabolism in plant tissues (Ge et al., 2018). As fruits ripen, the breakdown of starch into simpler sugars, including sucrose, enhances the sweetness and provides the energy necessary for cellular activities and the synthesis of vital metabolites (Saladié et al., 2015). This process is particularly evident in climacteric fruits, where sucrose accumulation is a key determinant of fruit quality and consumer appeal (Saladié et al., 2015; Wongmetha et al., 2015). Beyond its role in energy provision, sucrose functions as a signaling molecule that influences various physiological processes, including growth and development, and the plant's response to environmental stresses(Peng et al., 2020; Tian et al., 2021). For instance, sucrose has been shown to trigger signaling pathways that promote growth and stress responses in various plant species (Tian et al., 2021). The metabolic pathways involving sucrose are complex, with enzymes such as sucrose synthase and sucrose phosphate synthase playing critical roles in its synthesis and degradation during fruit maturation (Shan & Malladi, 2020). The accumulation of sucrose not only contributes to the organoleptic qualities of fruits but also facilitates the overall maturation process by supporting the metabolic demands of developing tissues (Wongmetha et al., 2015). In summary, sucrose is not merely a

sweetener but a vital metabolic intermediary that supports fruit development and maturation. Its dual role as an energy source and a signaling molecule underscores its importance in the life cycle of plants, particularly during the ripening phase when the transformation of carbohydrates is most pronounced (Ge et al., 2018; Saladié et al., 2015).

CONCLUSION

This research shows that there is a change in the texture of the banana kepok and California papaya in the ripening process. The texture of kepok bananas decreased from 3.66 kg/cm² to 0.56 kg/cm² between days 2 and 12 after harvest, while California papayas showed a reduction from 3.63 to 1.36 kg/cm². During the ripening process, the peak sucrose content was observed at 0.45° Brix for kepok bananas on day 12 and 11.38° Brix for California papayas on day 10.

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