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# Physicochemical Characteristics of Nata De Banana Produced From Ambon Banana Peels (*Musa paradisiaca L.*) Cultivated in The Highlands and Lowlands of Bengkulu Province, Indonesia

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**Abstract**

**Background:** Banana peel waste from Ambon bananas contains essential nutrients that support the growth of *Acetobacter xylinum* in nata production. Differences in cultivation environments, such as highland and lowland areas, may influence the composition of banana peels and subsequently affect the characteristics of nata de banana produced.
**Aims:** This study aimed to analyze the differences in characteristics of nata de banana produced from Ambon banana peels cultivated in highland and lowland areas, focusing on physical properties and sensory acceptance.
**Methods:** An experimental design was used with banana peels from highland and lowland areas as the differentiating variables. Data on nata characteristics were analyzed statistically using an independent sample t-test with SPSS version 23.
**Result:** The results showed significant differences in thickness and weight of nata de banana between the two sources. Nata produced from highland banana peel extract had greater thickness and weight. Organoleptic tests also indicated that nata from highland peels was more preferred in terms of color, texture, taste, and aroma.
**Conclusion:** Ambon banana peels from highland areas demonstrate higher potential as raw material for nata production, offering an effective approach to utilizing local natural resources and improving the management of banana peel waste.

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## INTRODUCTION

Nata is a white, water-insoluble, gelatinous food product that forms on the surface of a fermentation medium (Hasanin et al., 2023). Nata is produced through a fermentation process by the bacteria *Acetobacter xylinum* which synthesizes extracellular cellulose using nutrient sources in the form of carbon, nitrogen, and minerals from the fermentation medium (Ronggur et al., 2022). The resulting cellulose has a dense microfiber structure, high water content, and is low in calories, making it widely used as a functional food ingredient and diet product (Khan et al., 2023). Consuming nata contributes as a source of dietary fiber, which plays a role in improving digestive health, helping control blood glucose levels, and supporting weight management (Putri et al., 2024). Therefore, the demand for nata tends to increase as public awareness of the importance of healthy food consumption patterns increases (Kurniawan et al., 2025). In addition to its nutritional value, nata also has high economic value and has the potential to be developed as a sustainable biotechnology-based food product because it can be produced from local raw materials and organic waste (Kumari et al., 2023).

As demand increases, nata can be made from various fruit extracts as a nutrient source, one of which is Ambon banana peel (*Musa paradisiaca L.*) (Mishra et al., 2023). Ambon banana peel was chosen as an additional extract in nata production because it is still underutilized by the community and is generally left as waste (Wang et al., 2022). However, Ambon banana peel contains carbohydrates, proteins, and minerals that function as a source of carbon and nitrogen for the growth and activity of *Acetobacter xylinum* (Kumar et al., 2021). Using banana peel as a nata fermentation medium not only increases the added value of agricultural waste but also supports the concept of a circular economy and sustainability in the development of food biotechnology (Scott et al., 2025).

Ambon banana plants can grow in tropical areas, both in the lowlands and highlands, with a humid, hot, and humid tropical climate that favors banana growth. Ambon bananas found in Bengkulu Province are generally growing at two location, those are cultivated in the highlands and those are cultivated in the lowlands. Ambon bananas from the highlands are from Rejang Lebong Regency, Bengkulu Province (Indonesia), are cultivated at 600-700 meters above sea level. According to, Ambon bananas from Rejang Lebong have a sweet taste, soft, yellowish-white flesh, and a yellow-green skin with brown spots (Ronggur et al., 2025). The lowland Ambon bananas used are from Central Bengkulu Regency, at an altitude of 0-541 meters above sea level (Martinez et al., 2025).

Highland Ambon bananas from Rejang Lebong and lowland Ambon bananas from Central Bengkulu Regency exhibit several distinct characteristics. In terms of morphology, highland Ambon bananas generally have longer fruits compared to those grown in lowland areas (Martinez et al., 2025). Regarding peel color, highland Ambon bananas tend to be brownish-yellow, whereas lowland Ambon bananas are typically bright yellow (Thandavamoorthy et al., 2023). From a sensory perspective, highland Ambon bananas are considered sweeter and have a softer texture, while lowland Ambon bananas possess a relatively less sweet taste (Valenzuela-Cobos et al., 2024). These differences in physical and sensory attributes reflect the influence of environmental growing conditions, including soil type, climate, altitude, and cultivation practices, all of which contribute to variations in fruit quality and characteristics (Cobos et al., 2024).

Bananas were cultivated in the highlands have several advantages compared to cultivated bananas in the lowlands, including a sweeter taste, a fluffier texture, and higher nutritional content due to higher total soluble solids, citric acid, and flavonoid compound concentrations (Fauzana et al., 2023). Various studies have shown that differences in substrate source significantly affect nata thickness, yield, texture, fiber content, color, and flavor (Singh et al., 2023). This is because each raw material offers unique characteristics and performance metrics, which in turn influence the environmental conditions for the growth of *Acetobacter xylinum* bacteria (Zhao et al., 2025). Because of the importance of substrate selection, this study aimed to determine whether there are differences in the thickness and weight of nata produced from Ambon banana peel extract from highland bananas (Rejang Lebong Regency, Bengkulu) and Ambon bananas from lowland bananas (Central Bengkulu Regency, Bengkulu).

## METHOD

This study employed an experimental design consisting of two treatments: nata de banana produced from highland Ambon banana peels and nata de banana produced from lowland Ambon banana peels. The collected data were analyzed statistically using an independent samples *t*-test with SPSS version 23 to determine significant differences between treatments.

### a. Making Nata de Banana

He procedure for producing nata de banana was as follows. Banana peels were washed, cut into small pieces, and blended with water at a ratio of 2.5 kg of peels to 2,500 ml of water. The blended mixture was filtered to obtain banana peel extract. The filtrate was then boiled for 15 minutes, after which 15 g of granulated sugar and 3 g of food-grade urea were added as carbon and nitrogen sources, respectively. The heating process was stopped, and 10 ml of acetic acid was added to adjust the ph and minimize excessive acid evaporation.

The prepared medium was poured into plastic containers, each containing 250 mL, and covered with sterile newspaper secured with a rubber band. The medium was allowed to cool to a temperature between 28°C and 30°C (Rahmawati et al., 2025). Once cooled, 20 mL of *Acetobacter xylinum* starter culture was aseptically added by slightly opening the cover, which was then immediately resealed. Fermentation was carried out at room temperature (28–30°C) for 14 days in a clean, undisturbed environment. After incubation, the nata formed was evaluated for color, texture, aroma, and taste, and its thickness and wet weight were measured.

**b. Measurement of of Nata de Banana Thickness**

Measurements were made by separating the nata from the media, placing it on steril container, then draining it for 10 minutes. The thickness was then measured using a ruler or vernier caliper, and the average measurement was calculated. Thickness was calculated using the following formula:

Nata thickness = $\frac{t1+t2+t3+t4}{4}$

Note: t = nata thickness which is measured from four different sides

**c. Measurement of Nata de Banana Weight**

The cellulose weight of nata de banana was determined by weighing the nata layer formed in each treatment and replication. The formed nata (bacterial cellulose) was carefully separated from the fermentation liquid and drained to remove excess medium (Hikal et al., 2022). It was then weighed using a digital analytical balance. The measurements obtained from all replications were averaged to determine the mean cellulose weight for each treatment.

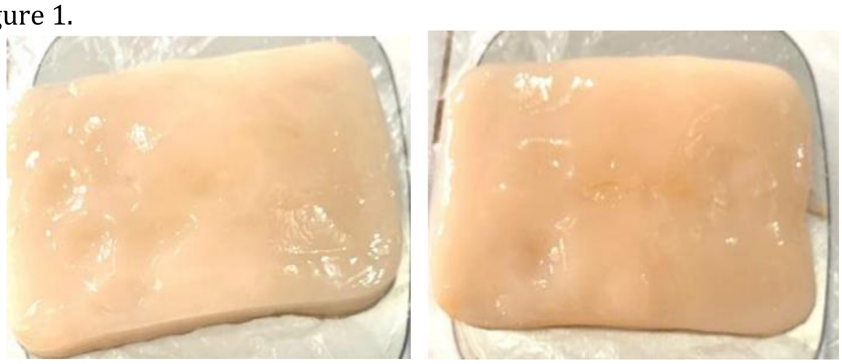
**d. Organoleptic Evaluation of Nata de Banana**

The organoleptic evaluation was conducted by serving 30 g of prepared nata samples in plastic cups to 30 untrained panelists. Each panelist was provided with a questionnaire to assess the sensory attributes of taste, color, aroma, and texture. The evaluation employed a five-point hedonic scale, where 1 = dislike very much, 2 = dislike, 3 = neutral, 4 = like, and 5 = like very much. The selection and participation of panelists were based on the requirements outlined in SNI 2346:2011 for sensory evaluation, which include: (a) willingness and interest in participating in organoleptic testing; (b) consistency in decision-making; (c) being in good health, free from ear, nose, and throat (ENT) disorders, not color blind, and without psychological disturbances; (d) no allergies or refusal toward the tested product; (e) abstaining from smoking, chewing gum, eating, or consuming soft drinks at least 20 minutes prior to testing; and (f) not conducting the test while experiencing influenza or eye disorders.

## RESULTS AND DISCUSSION

**Results:**

The results of nata de banana from Ambon bananas from highland and lowland areas were presented in Figure 1.



(a) (b)

**Figure 1**. (a) Results of Nata de Banana peel from the highlands, (b) Results of Nata de Banana peel from the lowlands

The results of thickness measurements indicated that nata de banana produced from highland Ambon banana peel extract reached a thickness of 2.0 cm, which was greater than that of nata produced from lowland Ambon banana peel extract, measuring 1.1 cm (Figure 2).

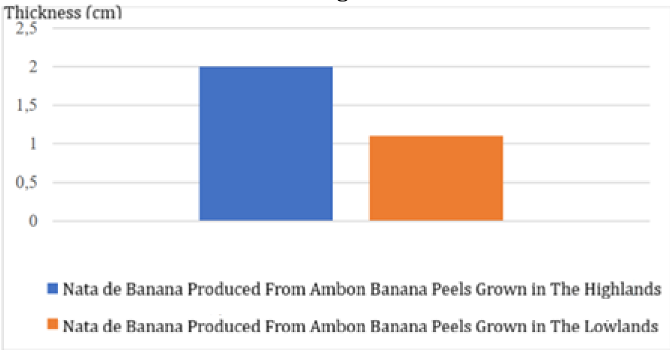



**Figure 2**. Chart of Nata de Banana Thickness

The results of the weight measurement showed that nata de banana produced from highland Ambon banana peel extract had a wet weight of 206 g, which was higher than that produced from lowland Ambon banana peel extract, with a weight of 123 g (Figure 3).

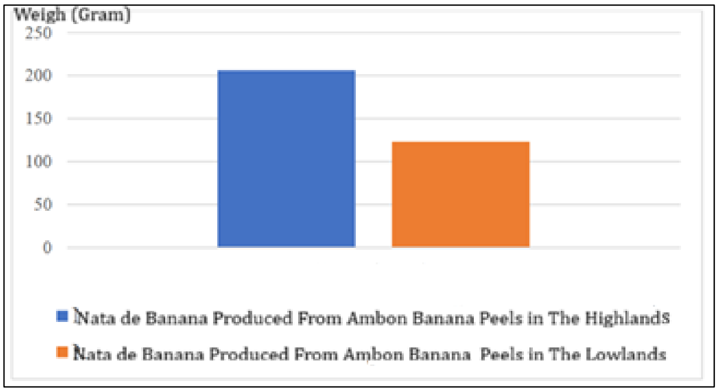



**Figure 3.** Chart of Nata de Banana Weight

Furthermore, the thickness and weight data of nata de banana were analyzed statistically using the Independent T-Test. Based on the results of the Independent T-Test on the comparison of nata weight, a significance of 0.000 <0.05 was obtained (Table 1) indicating that there was a difference in nata weight from the use of Ambon banana (*Musa paradisiaca L.*) peel extract in the highlands and lowlands.

**Table 1** Results of Independent T-Test Weight of Nata de Banana

| | | t-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference Lower | Upper |
| Hasilberatnata debananaskin | Equal variances assumed | 13.290 | 18 | .000 | 56.60000 | 4.25885 | 47.65249 | 65.54751 |
| | Equal variances not assumed | 13.290 | 11.065 | .000 | 56.60000 | 4.25885 | 47.23301 | 65.96699 |

Meanwhile, the results of the Independent T-Test on the comparison of nata thickness obtained a significance of 0.006 <0.05 (Table 2) indicating that there is a difference in nata thickness from the use of Ambon banana peel extract (*Musa paradisiaca L.*) in highland and lowland areas.

**Table 2** Results of the Independent T-Test for the Thickness of Nata de Banana

| | | t-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | 95% Confidence Interval of the Difference | |
| | | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
| Hasilketebalan natadebanana skin | Equal variances assumed | 3.083 | 18 | .006 | 6.6000 | 2.1406 | 2.1027 | 11.0973 |
| | Equal variances not assumed | 3.083 | 14.694 | .008 | 6.6000 | 2.1406 | 2.0291 | 11.1709 |

The use of Ambon banana peels, which contain high carbohydrates, can help *Acetobacter xylinum* bacteria produce cellulose, thus producing good-quality nata. The use of Ambon banana peel extracts from different regions, namely Ambon bananas (*Musa paradisiaca L.*) originating from Rejang Lebong (Curup) Regency and Ambon bananas originating from Central Bengkulu Regency, produces different nata weights and thicknesses. The difference in the weight of the resulting nata nata de banana is influenced by the thickness of the nata, because the thicker the nata, the heavier the nata produced. The weight of the nata is influenced by the thickness of the nata, the heavier the nata, the thicker the nata. Nata de banana extract from Ambon banana peels (*Musa paradisiaca L.*) from the highlands produces thick nata because there is a high carbohydrate content in the banana peels used. This is consistent who stated that the higher the carbohydrate content, the thicker the nata produced.

Furthermore, the difference in thickness of nata de banana using Ambon banana (*Musa paradisiaca L.*) peel extract from highland and lowland areas is thought to be closely related to the different chemical composition of the banana peels. Ambon banana peels from Rejang Lebong (Curup) Regency). That bananas grown in highland areas have several advantages compared to bananas grown in lowland areas, including a sweeter taste, a fluffier texture, and higher nutritional content due to higher total soluble solids, citric acid, and flavortic compound concentrations. Who stated that Ambon banana peel has a fairly high nutritional content consisting of carbohydrates with an average content of 3.96%, a fat content of 1.68% and a protein content of 0.64%.

Based on the organoleptic evaluation of nata de banana produced from highland and lowland Ambon banana peels, a higher level of preference was consistently observed for the highland treatment. In terms of color, 43.3% of panelists indicated the highest hedonic score (score 5) for the brownish-white appearance of nata derived from highland banana peels. Regarding texture, 73.3% of panelists assigned the highest hedonic rating to the chewy texture of the highland nata de banana. For taste, 30% of panelists gave the highest score to the slightly sweet flavor of the highland treatment. Similarly, 26.6% of panelists assigned the highest hedonic score to the aroma of the highland nata de banana, which was characterized by a less sour note. A spider web diagram illustrating the percentage distribution of panelists' preferences across sensory attributes is presented in Figure 4.

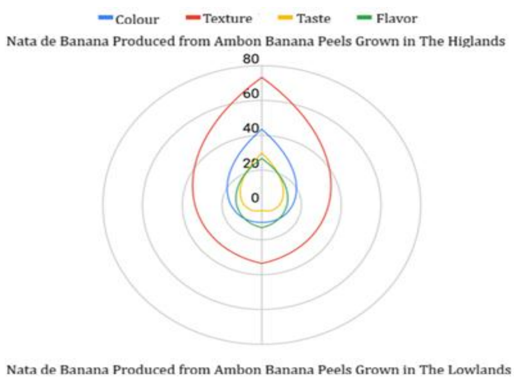



**Figure 4.** percentage of organoleptic test results for nata de banana

Overall organoleptic test results showed that the highest preference level among all panelists was for nata de banana from Ambon bananas from the highlands. This indicates that the quality of nata de banana from Ambon bananas from the highlands was well received by the panelists. Nata de banana is a conventional biotechnology product made from the aerobic fermentation of boiled Ambon banana (*Musa paradisiaca L.*) peel extract with the help of *Acetobacter xylinum* bacteria. *Acetobacter xylinum* is a bacterium that can grow in a medium containing carbon, nitrogen, and in acidic conditions with sufficient oxygen. The carbon source required by *Acetobacter xylinum* bacteria during the fermentation process can be obtained from banana peels, which have a high carbohydrate content. In an effort to utilize waste, the peels of Ambon bananas (*Musa paradisiaca L.*), which are predominantly cultivated in Bengkulu Province, can be used as a substrate or primary medium for nata production. The average results of organoleptic acceptance revealed that the panelists preferred nata de banana extract from Ambon banana skin from the highlands. In the organoleptic test of the color of nata de banana, the most preferred color of nata de banana was nata de banana extract from Ambon banana skin from the highlands with a percentage of 43.3%, which is very much liked. The color of nata is influenced by the raw materials used and the thickness of the nata itself. The color of the nata produced is brownish white caused by the color of the Ambon banana skin extract which is cloudy brown. In addition, the brownish white color of the nata de banana skin produced is also influenced by the thickness of the nata, because the thicker nata contains a lot of cellulose and is denser, causing the color of the nata to be darker. Who stated that thicker nata contains more and denser cellulose, this higher cellulose density is what causes the color of the nata to be darker.

In the organoleptic test of nata de banana texture, the most preferred texture of nata de banana was nata de banana extract from Ambon banana peel from the highlands with a percentage of 73.3%, which is very much liked. The texture of nata greatly influences consumer preference for the product. Nata is a food that is easy to bite and good for digestion, with a soft to chewy texture. In nata de banana extract from Ambon banana peel from the highlands, it has a higher thickness compared to nata de banana extract from Ambon banana peel from the lowlands. The texture of nata de banana is influenced by the formation of the density of the cellulose network formed in the fermentation medium. The denser the cellulose network formed, the resulting nata will have a good and chewy texture. The higher the thickness and fiber of nata, the chewier the nata. The texture of nata can be chewy because it contains a lot of cellulose and is dense.

In the organoleptic test of the taste of nata de banana, the most preferred level of taste of nata de banana is nata de banana extract of Ambon banana peel from the highland area with a percentage of 30%, which is very like. The taste of the nata produced is slightly sweet, this happens because before the taste test, the resulting nata is washed clean and soaked for 3 days by changing the water once a day, then boiled without adding sugar so that the resulting taste is pure from the fermented nata. Soaking and boiling nata are done to remove the sour taste at the beginning of harvesting. That to remove the sour taste in the resulting nata product, a soaking and cooking process is carried out so that the resulting nata has a bland taste. The duration of soaking and cooking is thought to cause different tastes in each treatment of the resulting nata. Organoleptic tests on the flavor of nata de banana showed that the most preferred flavor of nata de banana was nata de banana extract from Ambon banana peel from the highlands with a percentage of 26.6%, which is very much liked with the category of no flavor. The sour flavor in nata when harvested will disappear after soaking and boiling the nata in boiling water. With additional treatments such as boiling and soaking causes the sour flavor contained in nata to disappear. Therefore, with additional treatments there is no significant difference in the flavor in nata.

**Discussion:**

The use of Ambon banana peels, which contain high carbohydrates, can help *Acetobacter xylinum* bacteria produce cellulose, thus producing good-quality nata. The use of Ambon banana peel extracts from different regions produces different nata weights and thicknesses. The difference in weight is influenced by nata thickness because thicker nata tends to be heavier.

Nata produced from highland banana peels tends to be thicker due to higher carbohydrate content. Differences in thickness are also closely related to differences in chemical composition influenced by growing conditions such as altitude, soil, and climate.

Based on organoleptic evaluation, nata from highland peels showed higher preference in color, texture, taste, and aroma. The brownish-white color is influenced by raw material characteristics and cellulose density. The chewy texture is related to the denser cellulose network formed during fermentation. The taste differences are influenced by soaking and boiling processes that reduce acidity, while aroma differences tend to diminish after post-harvest treatment. Overall, fermentation conditions and substrate composition play an important role in determining nata quality.

Implications:

These findings indicate that banana peel waste from highland Ambon bananas has greater potential as a raw material for nata production. Utilizing this waste can support sustainable food production, increase the economic value of agricultural by-products, and promote environmentally friendly biotechnology applications.

Research contribution:

This study provides scientific evidence regarding the influence of growing altitude on the physicochemical and sensory characteristics of nata de banana. It also contributes to the development of alternative fermentation substrates from local agricultural waste and supports circular economy practices in food biotechnology

Limitations:

This study only compared two geographical sources and focused on thickness, weight, and organoleptic properties. Detailed chemical composition analysis of banana peels and optimization of fermentation parameters were not conducted, which may limit broader generalization.

Suggestions:

Future studies are recommended to analyze the nutritional and chemical composition of banana peels in more detail, evaluate different fermentation conditions, and test larger sample sizes. Exploring scalability and economic feasibility for industrial production is also suggested.

## CONCLUSION

Based on the results of this study, it can be concluded that the use of Ambon banana peel extract from highland and lowland areas resulted in differences in the thickness and weight of nata de banana skin. Higher thickness and weight were obtained when using highland Ambon banana peel extract. Organoleptic evaluation results indicated that the nata de banana extract from highland Ambron areas was the most preferred in terms of color, texture, taste, and aroma. Therefore, highland Ambon has higher potential for developing nata production by utilizing local natural resources while simultaneously improving the utilization of Ambon banana peel waste.

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## AUTHOR CONTRIBUTION STATEMENT

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