

The Effect of Sugar Concentration and Drying Time to Nata De Coco Characteristic

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Abstract

This study aimed to evaluate the effects of sugar concentration and drying time on the physical and chemical properties of nata de coco. A factorial completely randomized design with two factors sugar concentration (40%, 50%, and 60% w/v) and drying time (7, 8, and 9 hours) was used, with three replications per treatment. Physical parameters (texture, color, rehydration) and chemical parameters (moisture content, total sugar) were measured. Results showed that sugar concentration significantly affected color (L), rehydration, moisture, and total sugar, while drying time significantly influenced texture, color (L*, a*), rehydration, moisture, and total sugar. The interaction between factors was not significant. The optimal condition was 40% sugar and 7-hour drying, producing 18.01% moisture, 64.67 °Brix total sugar, 117.0 gf texture, color values of L* = 63.0%, a* = 4.17%, b* = 10.93%, and 139.45% rehydration.*

Keywords: *nata de coco, drying time, sugar concentration, Physical and chemical properties*

INTRODUCTION

Nata is a beverage product composed of cellulose (dietary fiber) produced through a fermentation process involving microorganisms, particularly *Acetobacter xylinum* (Pambayun, 2002). Nata has a gelatinous texture similar to agar or palm fruit and is commonly used as a filler in ice cream, fruit cocktails, and yogurt (Rizal et al., 2013). Nata exhibits a white color and is composed of about 98% water, with cellulose formed from sugar through the activity of *Acetobacter xylinum* (Syukroni et al., 2013). Nata de coco, with its high cellulose content, aids digestion and offers a low-calorie option for diet foods, while also supplying B vitamins (B1 and B2) and vitamin C (Suzanni et al., 2020).

Acetobacter xylinum plays an essential role in nata production and requires several growth media components such as carbon, nitrogen, minerals, and vitamins. Currently, nata is not only produced from coconut water but also from various food-processing wastes, provided that sufficient carbon and nitrogen sources as well as suitable growth conditions such as pH and temperature are met (Widiyaningrum et al., 2017). The

carbon source commonly used is sucrose, while the nitrogen source is ammonium sulfate (ZA) (Santosa et al., 2021). Previous studies have shown that nata can be produced from various substrates, including tofu wastewater (Iryandi et al., 2014), pineapple peel (Sutanto, 2012), sugarcane sap waste (Arifiani et al., 2015), and jicama (Melina, 2016). Among these, coconut water waste is the most widely available raw material and is commonly used to produce nata de coco (Ratnawati, 2007) because it contains relatively complete nutrients suitable for *Acetobacter xylinum* growth (Syukroni et al., 2013).

Nata de coco is widely produced by small and medium enterprises (SMEs); however, issues related to shelf life, handling, and distribution are still encountered. The shelf life of preservative-free nata de coco in packaging is 7 days at 28 °C, 9 days at 25 °C, 23 days at 15 °C, and up to 2 months at 5 °C (GP, 2018). Nata de coco is also highly susceptible to mold contamination, requiring immersion in clean water during storage and distribution. This condition increases product weight and reduces storage efficiency during

transportation (Ariyanti & Suherman, 2014).

To address these issues, drying is considered an effective method to extend shelf life and facilitate handling and distribution by producing dried nata de coco (Simon, 2020). Drying causes changes in color, texture, and aroma of food products (Huriawati et al., 2016). Nata de coco may be dried within a 45–75 °C range; however, temperatures exceeding 75 °C can adversely affect its chemical and physical properties due to excessive heat and mass transfer (Diza et al., 2014).

Hastuti (2020) observed that drying conditions significantly affected moisture content, total sugar, color, and rehydration of instant nata de coco, though the low rehydration values indicate the necessity for further studies.

Before drying, nata is commonly soaked in sugar solution. Sugar soaking improves sweetness and reduces moisture content through osmotic dehydration. Sugar acts as an osmotic agent that draws water out of the material, thereby reducing moisture content and water activity (Sari & Nelwan, 2019). Sugar also softens nata texture by filling cell pores and improving structural integrity (Hasbullah & Muhandri, 2016). Consequently, it is essential to examine the effects of sugar concentration and drying time on the quality attributes of dried nata de coco.

Experimental Design

The study utilized a factorial CRD with two factors: sugar concentration (40%, 50%, 60% w/v) and drying time (7, 8, 9 hours). Data were analyzed via ANOVA, and treatments with significant effects were subjected to the 5% HSD test for mean comparison.

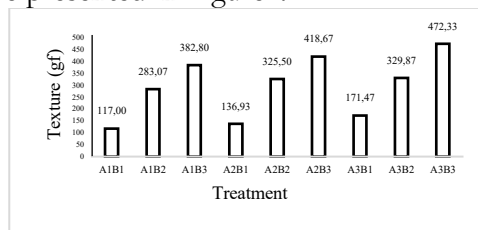
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Physical Characteristics

Texture

Texture is one of the test parameters used to evaluate a product, as it indicates the level of hardness. The average texture of dried

nata de coco increased from 117.0 gf under A1B1 conditions (40% sugar, 7 h) to 472.3 gf under A3B3 (60% sugar, 9 h). The average texture values of dried nata de coco are presented in Figure 4.1.



Sugar concentration: Drying time:
A1 = 40% (w/v) B1 = 7 hours
A2 = 50% (w/v) B2 = 8 hours
A3 = 60% (w/v) B3 = 9 hours

Figure 4.1. Average texture values (gf) of dried nata de coco

Drying time (treatment B) significantly affected the texture of dried nata de coco, whereas sugar concentration (treatment A) and their interaction showed no significant effect.

Table 4.1. HSD test (5%) on the effect of drying time on the texture of nata de coco

Treatment	Average texture (gf)	HSD 5% = 4,51
B ₁ (drying time 7 hours)	141,80	A
B ₂ (drying time 8 hours)	312,81	B
B ₃ (drying time 9 hours)	424,60	C

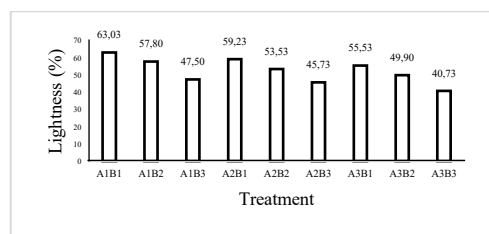
The results of the HSD test at the 5% significance level presented in Table 4.1 indicate that each treatment differed significantly from the others. A longer drying time resulted in higher texture values of nata de coco.

According to Rajkumar and Kulanthaisami (2006) as cited in Susilo (2012), during the drying process, heat transfer occurs to the nata, followed by mass transfer of water vapor from the interior to the surface and subsequently from the surface to the surrounding air. Nata de coco is a cellulose-based compound, which is a polymer of glucose. Cellulose contains hydroxyl (OH) groups,

and during the drying process, hydrogen bonds between water molecules—representing the weakest interactions between cellulose and water—are broken. The hydrogen bonds between the OH groups of water and those of cellulose are disrupted, causing partial release of water and allowing cellulose surfaces to move closer to each other. This bond-breaking process continues until only a monomolecular layer of water remains between the two cellulose surfaces, resulting in a further reduction of moisture content within the cellulose structure (Aditama & Ardhyanta, 2017). According to Winarno (1982) as cited in Asnawi et al. (2013), the greater the amount of water evaporated and the lower the remaining moisture content of the material, the higher the resulting texture value (Wijayanti et al., 2011).

Color Lightness (L*)

Lightness (L*) is an indicator used to determine the brightness level of a material's color. The L* value ranges from 0 (black) to 100 (white) (Munsell, 1997). An L* value closer to 100 indicates a higher level of brightness (whiteness), whereas an L* value closer to 0 indicates lower brightness (darker color) (Effendi et al., 2015). The average lightness values of dried nata de coco ranged from 40.73% in treatment A3B3 (60% sugar concentration and 9 hours of drying time) to 63.03% in treatment A1B1 (40% sugar concentration and 7 hours of drying time). The average lightness values of dried nata de coco are presented in Figure 4.2.



Sugar concentration: Drying time:
A1 = 40% (w/v) B1 = 7 hours
A2 = 50% (w/v) B2 = 8 hours

A3 = 60% (w/v) B3 = 9 hours

The analysis of variance indicated that both treatment A (sugar concentration) and treatment B (drying time) significantly influenced the lightness of dried nata de coco, while the interaction between sugar concentration and drying time did not show a significant effect on lightness. The results of the HSD test at the 5% significance level for treatment A (sugar concentration) and treatment B (drying time) on the lightness of dried nata de coco are presented in Tables 4.2 and 4.3.

Table 4.2. HSD test at the 5% significance level on the effect of sugar concentration on the lightness of dried nata de coco

Treatment	Average lightness (%)	HSD 5% =
A ₃ (sugar concentration 60%)	48,72	A
A ₂ (sugar concentration 60%)	52,83	a b
A ₁ (sugar concentration 60%)	56,11	B

The results of the HSD test at the 5% significance level presented in Table 4.2 indicate that treatment A₃ (60% sugar concentration) was not significantly different from treatment A₂ (50% sugar concentration) but was significantly different from treatment A₁ (40% sugar concentration).

Table 4.2 shows that higher sugar concentrations resulted in lower lightness values. The decrease in lightness observed with increasing sugar concentration was attributed to an increase in total soluble solids due to the dissolution of sucrose in water. Granulated sugar is sucrose in solid form, which is a carbohydrate component with relatively high solubility in water. Therefore, increasing the amount of sugar added leads to a higher concentration of

soluble solids. An increase in total soluble solids subsequently reduces the brightness of the sample, resulting in lower lightness values (Pratama et al., 2012).

Table 4.3. HSD test at the 5% significance level on the effect of drying time on the lightness of dried nata de coco

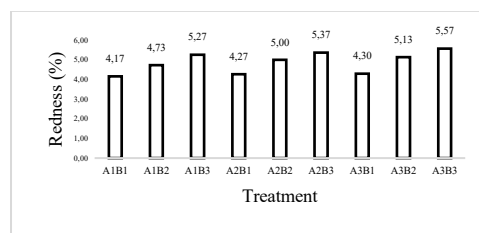
Treatment	Average lightness (%)	HSD 5% = 4,51
B ₃ (drying time 9 hours)	44,66	a
B ₂ (drying time 8 hours)	53,74	b
B ₁ (drying time 7 hours)	59,27	c

The results of the HSD test at the 5% significance level presented in Table 4.3 indicate that each treatment differed significantly from the others. Table 4.3 shows that a longer drying time resulted in lower lightness values. The decrease in lightness was attributed to a reduction in moisture content due to increased evaporation of water from the nata as the drying time increased. According to Buckle et al. (2007), as cited in Yunita and Rahmawati (2015), greater amounts of water evaporation lead to higher total soluble solids, which in turn reduce the brightness of the nata, resulting in lower lightness values.

Redness (a*)

Redness (a*) is a color parameter that represents the color spectrum from green to red. The redness value ranges from -80 (green) to +100 (red) (Amanto et al., 2015). The average redness values of dried nata de coco ranged from 4.17% in treatment A1B1 (40% sugar concentration and 7 hours of drying time) to 5.57% in treatment A3B3 (60% sugar concentration and 9 hours of drying time). The average redness values of dried nata de coco are presented in Figure

4.3.



Sugar concentration: Drying time:

A1 = 40% (w/v) B1 = 7 hours
A2 = 50% (w/v) B2 = 8 hours
A3 = 60% (w/v) B3 = 9 hours

Figure 4.3. Average redness values (%) of dried nata de coco

The analysis of variance results showed that factor B (drying duration) significantly influenced the redness of dried nata de coco, while factor A (sugar concentration) and the interaction between sugar concentration and drying duration did not exhibit a significant effect on redness. Furthermore, the results of the HSD test at the 5% significance level regarding the impact of drying time on the redness of dried nata de coco are summarized in Table 4.4.

Table 4.4. HSD test at the 5% significance level on the effect of drying time on the redness of dried nata de coco

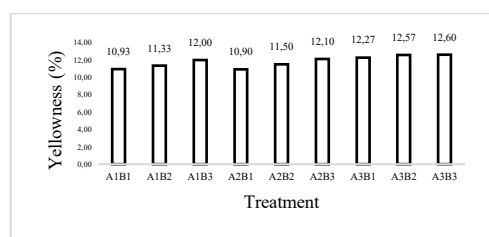
Treatment	Average redness (%)	HSD 5% = 0,26
B ₁ (drying time 7 hours)	44,66	a
B ₂ (drying time 8 hours)	53,74	b
B ₃ (drying time 9 hours)	59,27	b

The redness value in treatment B1 (7 hours of drying time) was significantly different from that in treatment B2 (8 hours of drying time) and treatment B3 (9 hours of drying time). An increase in drying time resulted in higher redness values. Longer drying times promote a greater extent of Maillard reactions, which continue to occur as the process proceeds. According to Zalizar et al. (2016), the Maillard reaction is a non-

enzymatic browning reaction that occurs due to interactions between amino groups of proteins and carbonyl groups of reducing sugars, producing brown-colored compounds known as melanoidins. The amino groups originate from the protein content of nata de coco, while the reducing sugars are derived from glucose and fructose monomers produced by the breakdown of sucrose during drying. The browning reaction in nata can be accelerated by prolonged drying time, thereby increasing the intensity of the Maillard reaction (Andragogi et al., 2018). An increase in the intensity of the Maillard reaction causes the color of nata to become darker or browner, resulting in higher redness values (Larasati et al., 2019).

Yellowness (b*)

Yellowness (b*) represents the color intensity ranging from yellow (positive values) to blue (negative values), where higher yellowness values indicate a stronger tendency toward yellow coloration in the product or material (Manasika & Widjanarko, 2015). The average yellowness values of dried nata de coco ranged from 10.93% in treatment A1B1 (40% sugar concentration and 7 hours of drying time) to 12.60% in treatment A3B3 (60% sugar concentration and 9 hours of drying time). The average yellowness values of dried nata de coco are presented in Figure 4.4.



Sugar concentration: Drying time:
A1 = 40% (w/v) B1 = 7 hours
A2 = 50% (w/v) B2 = 8 hours
A3 = 60% (w/v) B3 = 9 hours

Figure 4.4. Average yellowness values (%) of dried nata de coco

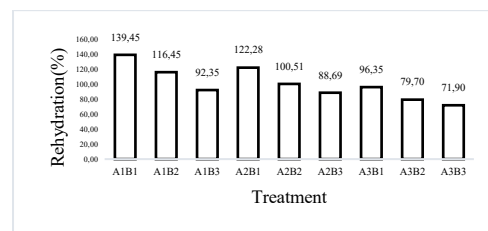
The results of the analysis of variance demonstrated that treatment A (sugar

concentration), treatment B (drying time), and the interaction between both factors did not significantly affect the yellowness values of dried nata de coco.

Figure 4.4 shows that higher sugar concentrations and longer drying times tended to increase the yellowness values of nata de coco. The increase in yellowness was attributed to the Maillard reaction, which can be accelerated by the drying process and higher sugar concentrations (Andragogi et al., 2018). The Maillard reaction produces yellowish-brown coloration; therefore, higher sugar concentrations and longer drying times result in a more yellowish-brown color of dried nata de coco, leading to increased yellowness values.

Rehydration

Rehydration in this study was evaluated using dried nata de coco samples. The mean rehydration values ranged from 71.90% in treatment A3B3 (60% sugar concentration and 9 hours of drying time) to 139.45% in treatment A1B1 (40% sugar concentration and 7 hours of drying time). The rehydration test results of dried nata de coco are presented in Figure 4.5.



Sugar concentration: Drying time:
A1 = 40% (w/v) B1 = 7 hours
A2 = 50% (w/v) B2 = 8 hours
A3 = 60% (w/v) B3 = 9 hours

Figure 4.5. Average rehydration values (%) of dried nata de coco

The analysis of variance revealed that treatment A (sugar concentration) and treatment B (drying time) significantly influenced the rehydration of dried nata de coco, while the interaction between these two factors did not show a significant effect on rehydration values. Furthermore, the

results of the HSD test at the 5% significance level for the effects of sugar concentration and drying time on the rehydration of dried nata de coco are presented in Tables 4.5 and 4.6.

Table 4.5. HSD test at the 5% significance level on the effect of sugar concentration on the rehydration of dried nata de coco

Treatment	Average Rehydration (%)	HSD 5% = 4,51
A ₃ (sugar concentration 60%)	82,65	a
A ₂ (sugar concentration 50%)	103,83	b
A ₁ (sugar concentration 40%)	116,08	b

The results of the HSD test at the 5% significance level presented in Table 4.5 indicate that treatment A3 (60% sugar concentration) was significantly different from treatments A2 (50% sugar concentration) and A1 (40% sugar concentration), whereas treatment A2 (50% sugar concentration) was not significantly different from treatment A1 (40% sugar concentration). An increase in sugar concentration during nata soaking resulted in a decrease in rehydration values. According to Neuma (1972), as cited in Histifarina et al. (2004), rehydration capacity can be influenced by the elasticity of the cell wall, loss of differential permeability of the protoplasmic membrane, loss of cell turgor pressure, and hydrogen bonding of macromolecules.

According to Arsyad (2018), cellulose contains hydroxyl (OH) groups that can form hydrogen bonds with the hydroxyl groups of water, thereby enhancing water absorption. During the drying process, the sugar solution penetrates and fills the pore layers within nata de coco, causing water to be released and evaporated,

while the sugar solution subsequently crystallizes and becomes entrapped within the nata, filling the cavities of some cells whose fluids have diffused out. When water is added, nata can readily reabsorb water (rehydration) because the sugar crystals within the cavities dissolve, allowing water to re-enter the nata structure.

However, higher sugar concentrations result in a greater number of sugar crystals entering the nata and filling the pore spaces, which can damage the cellulose cell walls and reduce their elasticity. This reduction in cell wall elasticity decreases the ability of cellulose to reabsorb water, thereby leading to a decrease in the rehydration value of nata.

Table 4.6. HSD test at the 5% significance level on the effect of drying time on the rehydration of dried nata de coco

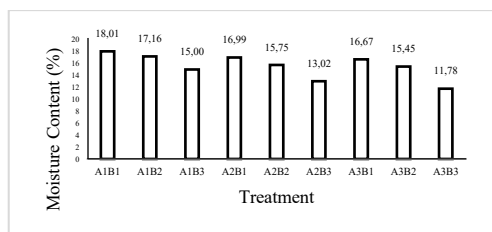
Treatment	Average Rehydration (%)	HSD 5% = 0,26
B ₃ (drying time 9 hours)	44,66	a
B ₂ (drying time 8 hours)	53,74	b
B ₁ (drying time 7 hours)	59,27	b

The results of the HSD test at the 5% significance level presented in Table 4.6 indicate that treatment B3 (9 hours of drying time) was not significantly different from treatment B2 (8 hours of drying time) but was significantly different from treatment B1 (7 hours of drying time). Table 4.6 shows that increasing drying time resulted in a decrease in the rehydration values of dried nata de coco. In treatment B3 (9 hours of drying time), the rehydration value decreased. This reduction in rehydration was attributed to prolonged drying time. According to Histifarina et al. (2004), the ability of dried materials to absorb water is reduced when subjected to high sugar concentrations and excessive heat treatment over extended heating durations, which

decreases the elasticity of the cell walls. Consequently, the water absorption capacity of the material declines, leading to a reduced rehydration capacity.

Chemical Characteristics Moisture Content

Moisture content is one of the key indicators that determine the quality of food products, as it affects texture, flavor, and appearance. In this study, the moisture content of nata de coco was analyzed using dried nata de coco samples. According to the quality standard for dried fruit preserves (SNI No. 1718-83), the maximum allowable moisture content is 25%. The average moisture content of dried nata de coco ranged from 11.78% in treatment A3B3 (60% sugar concentration and 9 hours of drying time) to 18.01% in treatment A1B1 (40% sugar concentration and 7 hours of drying time). Therefore, the moisture content obtained in this study met the established standard. The results of moisture content measurements of dried nata de coco are presented in Figure 4.6.



Sugar concentration: Drying time:
A1 = 40% (w/v) B1 = 7 hours
A2 = 50% (w/v) B2 = 8 hours
A3 = 60% (w/v) B3 = 9 hours

Figure 4.6. Average moisture content values (%) of dried nata de coco

The analysis of variance results demonstrated that treatment A (sugar concentration) and treatment B (drying time) significantly affected the moisture content of dried nata de coco, while the interaction between these two factors did not have a significant influence on the final moisture content. Moreover, the findings of the HSD test at the 5% significance level regarding the effects of sugar concentration

and drying time on the moisture content of dried nata de coco are presented in Tables 4.7 and 4.8.

Table 4.7. HSD test at the 5% significance level on the effect of sugar concentration on the moisture content of dried nata de coco

Treatment	Average moisture content (%)	HSD 5% = 4,51
A ₃ (sugar concentration 60%)	14,63	a
A ₂ (sugar concentration 50%)	15,25	a b
A ₁ (sugar concentration 40%)	16,72	b

The results of the HSD test at the 5% significance level presented in Table 4.7 indicate that treatment A₃ (60% sugar concentration) was not significantly different from treatment A₂ (50% sugar concentration) but was significantly different from treatment A₁ (40% sugar concentration). Higher sugar concentrations used during the soaking of nata de coco resulted in lower moisture content.

According to Maulidiah et al. (2014), at high sugar solution concentrations, sugar penetrates the material and fills its pores, while water within the material is released, leading to a reduction in moisture content. Granulated sugar (sucrose) has stronger hygroscopic properties compared to other sugars, enabling it to bind water more effectively (Andragogi et al., 2018). According to Pratiwi (2007), the addition of sugar to food products at high concentrations (at least 40% total soluble solids) reduces the water activity of the product, thereby decreasing its moisture content.

Table 4.8. HSD test at the 5% significance level on the effect of drying time on the

moisture content of dried nata de coco

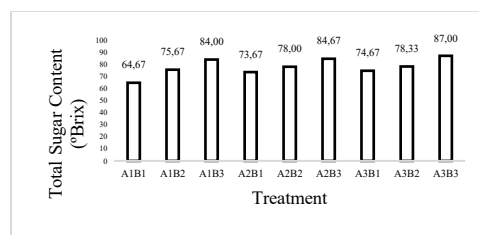
Treatment	Average moisture content (%)	HSD 5% = 1,74
B ₃ (drying time 9 hours)	13,26	a
B ₂ (drying time 8 hours)	16,12	b
B ₁ (drying time 7 hours)	17,22	b

The results of the HSD test at the 5% significance level indicated that treatment B₃ (9 hours of drying time) was significantly different from treatment B₂ (8 hours of drying time) and treatment B₁ (7 hours of drying time), whereas treatment B₂ (8 hours of drying time) was not significantly different from treatment B₁ (7 hours of drying time). Table 4.8 shows that longer drying times resulted in lower moisture content of nata de coco. According to Irzam and Harijono (2014), increasing drying time enhances the ability of the material to release water from its surface. Drying causes the hydrogen bonds between the hydroxyl (OH) groups of water and those of cellulose to break, allowing some of the water to be released and bringing cellulose surfaces closer together, thereby reducing the moisture content within the cellulose structure (Aditama & Ardhyanta, 2017).

Total Sugar Content

Total sugar content is expressed in degrees Brix (°Brix) (Tamam et al., 2015). According to Mukaromah et al. (2010), Brix is a unit representing the percentage of total dissolved solids in a solution (grams per 100 mL of solution), calculated as sucrose. The mean total sugar content of dried nata de coco varied from 64.67 °Brix in treatment A1B1 (40% sugar concentration and 7 hours of drying time) to 87.00 °Brix in treatment A3B3 (60% sugar concentration and 9 hours of drying time). The results of total sugar content measurements in dried

nata de coco are illustrated in Figure 4.7.



Sugar concentration: Drying time:
A1 = 40% (w/v) B1 = 7 hours
A2 = 50% (w/v) B2 = 8 hours
A3 = 60% (w/v) B3 = 9 hours

Figure 4.7. Average total sugar content (°Brix) of dried nata de coco

The analysis of variance results indicated that treatment A (sugar concentration) and treatment B (drying time) significantly influenced the total sugar content, while the interaction between these two factors did not show a significant effect on total sugar levels. Furthermore, the outcomes of the HSD test at the 5% significance level for the effects of sugar concentration and drying time are presented in Tables 4.9 and 4.10.

Table 4.9. HSD test at the 5% significance level on the effect of sugar concentration on the total sugar content of dried nata de coco

Treatment	Total sugar content (%)	HSD 5% = 4,66
A ₁ (sugar concentration 40%)	74,78	a
A ₂ (sugar concentration 50%)	78,78	a b
A ₃ (sugar concentration 60%)	80,00	b

The results of the HSD test at the 5% significance level presented in Table 4.9 indicate that treatment A₁ (40% sugar concentration) was not significantly different from treatment A₂ (50% sugar concentration) but was significantly different from treatment A₃ (60% sugar concentration), while treatment A₂ (50%

sugar concentration) was not significantly different from treatment A3 (60% sugar concentration).

Table 4.9 shows that increasing sugar concentration led to higher total sugar content. The addition of granulated sugar during the soaking of nata de coco increased the total sugar content of dried nata de coco. This finding is consistent with Luthony (1990), as cited in Yunita and Rahmawati (2015), who reported that higher sugar concentrations result in increased total sugar content. This occurs because sugar solutions consist of sucrose and several non-sucrose components; therefore, an increase in sugar concentration leads to a higher total sugar content.

Table 4.10. HSD test at the 5% significance level on the effect of drying time on the total sugar content of dried nata de coco

Treatment	Average total sugar content (%)	HSD 5% = 4,66
B1 (drying time 7 hours)	71,00	a
B ₂ (drying time 8 hours)	77,33	b
B3(drying time 9 hours)	85,22	c

The results of the HSD test at the 5% significance level presented in Table 4.10 indicate that each treatment differed significantly from the others. Table 4.10 shows that increasing drying time resulted in higher total sugar content in dried nata de coco. Longer drying processes cause greater evaporation of water from the material, leading to a reduction in moisture content and consequently an increase in total sugar content. This finding is consistent with Sutrisno (2014), who stated that the drying process affects sugar content by reducing moisture content, thereby increasing the percentage of total sugar.

Conclusions

The conclusions drawn from the results of

this study are as follows:

1. Sugar concentration significantly affected color (lightness, L*), rehydration capacity, moisture content, and total sugar content, while drying time had a significant influence on texture properties, color attributes (lightness, L* and redness, a*), rehydration, moisture content, and total sugar content. Meanwhile, the interaction between sugar concentration and drying time did not have a significant effect on any of the evaluated parameters.
2. The rehydration capacity of nata de coco decreased with increasing sugar concentration and drying time. This reduction was attributed to decreased elasticity of the cell walls due to higher sugar concentrations filling the pores and cavities of the nata structure, as well as excessive heat treatment resulting from prolonged drying time.
3. The moisture content of dried nata de coco produced in this study ranged from 11.78% to 18.01%. These values meet the quality requirements for dried fruit preserves according to the Indonesian National Standard (SNI No. 1718-83), which specifies a maximum moisture content of 25%.
4. The best treatment was A1B1 (40% sugar concentration and 7 hours of drying time), which resulted in a moisture content of 18.01%, total sugar content of 64.67 °Brix, texture value of 117.0 gf, color characteristics (lightness value of 63.0%, redness value of 4.17%, and yellowness value of 10.93%), and a rehydration value of 139.45%.

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