The Effect of Acidity Level (pH) and Palm Sugar Sucrose Levels on the Quality of Brown Sugar

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Abstract

Research on the effect of acidity level (pH) and sucrose levels of palm sugar has been successfully carried out. This study aims to determine the effect of acidity level (pH) and sucrose levels of palm sugar on the quality of brown sugar produced. The level of acidity (pH) of palm sugar is set at pH (3, 4, 5, 6, and 7). The quality of brown sugar is divided into three categories, namely quality 1 (high), 2 (moderate), and 3 (low). The sucrose content of palm sugar at pH (3 – 7) was determined by the Luff Schoorl method. The quality of brown sugar was determined organoleptically. The results of determining the sucrose content of palm sugar by Luff Schoorl method at pH (3, 4, 5, 6, and 7) were respectively (11.30, 12.25, 14.17, 15.10 and 16.42%). The results of organoleptic determination of brown sugar quality showed that: (1) palm sugar with sucrose content of 11.30% (pH 3) and 12.25% (pH 4) produced low quality brown sugar; (2) palm sugar with sucrose content of 14.17% (pH 5) and 15.10% (pH 6) produced medium quality brown sugar; (3) palm sugar with a sucrose content of 16.42% (pH 7) produces high quality brown sugar. So, the level of acidity (pH) and sucrose levels of palm sugar affect the quality of brown sugar. The lower the pH and sucrose content of palm sugar, the lower the quality of the brown sugar produced. Conversely, the higher the pH and sucrose content of palm sugar, the higher the quality of the brown sugar produced. Therefore, the quality of palm sugar needs to be maintained so that the pH and sucrose content do not decrease so that the brown sugar produced is of high quality. The results of testing the quality of brown sugar based on SNI-01-3743-1995 show that brown sugar produced from palm sugar at pH 5 – 7 meets SNI requirements. Meanwhile, brown sugar produced from palm sugar at pH 3 and 4 does not meet SNI requirements.

Keywords: *acidity level (pH), sucrose, palm sugar, brown sugar quality*

INTRODUCTION

One of the rural community handicraft businesses that deserves special attention related to efforts to improve and improve the quality of agricultural products and processed products is brown sugar processing (Suwanti *et al*., 2021). Since the start of people making brown sugar until now, not much effort has been made to improve its quality, including processing methods that are easy, cheap and avoid things that result in a decrease in the quality of brown sugar.

Based on our daily observations, it is common to find brown sugar that is not hard, melts easily, has a blackish brown color, or even remains in a clay form. All of this can be suspected of failure in

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processing, for example, burning occurs, not stirring frequently, the heat is too high, it takes too long to boil, or because the quality of the palm sugar is not good (Pontoh *et al*., 2019).

In general, damage to palm sugar occurs due to the activities of microorganisms that grow and reproduce in the palm sugar. Palm sugar contains 14.90% sucrose, 11.28% starch, 0.20% protein, 0.02% fat, 0.24% ash, and 73.36% water (Pontoh *et al*., 2019). This composition of substances allows microorganisms to grow and reproduce in the palm sugar (Yunita *et al*., 2017). Therefore, under normal circumstances, palm sugar as a result of tapping will easily be damaged due to being mixed with bacteria.

Damage to palm sugar due to bacteria will cause a sour taste. Palm sugar that is already sour, very difficult to repair again. If it is processed into brown sugar, the resulting brown sugar will become soft and melt easily. This is because bacteria can convert sucrose in palm sugar into fructose, glucose, and vinegar which cannot crystallize or condense (Yunita *et al*., 2017).

Based on direct observation of the processing of brown sugar, it turns out that the same methods, tools and processing can produce brown sugar of varying quality. This incident is thought to be caused by differences in the level of acidity and sucrose levels of palm sugar which is processed into brown sugar. Therefore, this study aims to determine the effect of acidity level (pH) and sucrose levels of palm sugar on the quality of brown sugar produced.

The results showed that the level of acidity (pH) and sucrose levels of palm sugar had an effect on the quality of brown sugar. The lower the pH and sucrose content of palm sugar, the lower the quality of the brown sugar produced. Conversely, the higher the pH and sucrose content of palm sugar, the higher the quality of the brown sugar produced. Therefore, the quality of palm sugar needs to be maintained so that the pH and sucrose content do not decrease so that the brown sugar produced is of high quality. The results of testing the quality of brown sugar based on SNI-01-3743-1995 show that brown sugar produced from palm sugar at pH 5–7 meets SNI requirements. Meanwhile, brown sugar produced from palm sugar at pH 3 and 4 does not meet SNI requirements.

METHODOLOGY

The tools used are pestle, plastic basin, bamboo tube, mould, dried banana leaves, palm fiber, plastic jerry can (Luhur), gas stove (Sanyo), pot (Halco), machete (Matahari), ice flask (Iqloo), boiling stones, substance bottles, weighing bottles, spray bottles, burettes (SGB), porcelain dishes (Glastronic), glass funnels (Jena), large cups, beakers (Pyrex), measuring cups (Glastronic), tripods, asbestos gauze, pH paper (E. Merck), filter paper (Whatman), Erlenmeyer flask (Pyrex), volumetric flask (RHG), spirit lamp, drying cabinet (Memmert), analytical balance (Mettler), rough balance (Ohaus), water bath, glass stirrer, cooling back (Pyrex), dropping pipette, measuring pipette (BTL), volume pipette (BTL), filter (Lion Star), plastic hose, metal spoon, bamboo spoon, substance spoon, stand and clamp, stopwatch (Hanhart Amigo), a thermometer (GDR), a plastic jar (Lion Star), and a frying pan (Halco).

The materials used were water, alcohol p.a., starch, hydrochloric acid p.a., citric acid p.a., sulfuric acid p.a., aquabidest, ice cubes, phenolphthalein indicator (PP), starch indicator, potassium iodide p.a., chloroform p.a., potassium iodate p.a., candlenut, sodium phosphate p.a., sodium hydroxide p.a., sodium thiosulfate p.a., lead acetate p.a., mercury(I) iodide p.a., palm sugar, Luff Schoorl reagent, sodium carbonate p.a., copper sulfate p.a., lead acetate p.a., and lead oxide p.a.

Determination of Palm Sugar Sucrose Levels at pH 3-7 with the Luff Schoorl Method

Palm sugar (2.5 g) at pH 3-7 was put into a beaker and diluted with aquabidest (50 mL). The palm sugar solution was put into a 100 mL volumetric flask and adjusted with aquabidest to the mark and then shaken. Palm sugar solution (50 mL) was put into a 250 mL volumetric flask and half alkaline lead acetate (10 mL) was added and then shaken. A 10% sodium phosphate solution (15 mL) is added to the palm sugar solution to precipitate excess lead acetate. To test whether all of the lead acetate has precipitated, the palm sugar solution is dripped with sodium phosphate (1-2 drops). If no precipitate appears, it means that the addition of sodium phosphate is considered sufficient. Palm sugar solution in a 250 mL volumetric flask was diluted with aquabidest to the mark, shaken 12 times, allowed to stand for 30 minutes and then filtered. Palm sugar filtrate was stored for testing sucrose levels before and after inversion (Baedhowie and Pranggonowati, 2020; Lubis *et al*., 2022; Pradnyana *et al*., 2014; Siregar and Maylia, 2017).

Before Inversion

Palm sugar filtrate (10 mL), aquabidest (15 mL), Luff reagent (25 mL), and a few boiling stones were put into a 500 mL volumetric flask with a lid. The volumetric flask was connected to the reverse cooler and boiled in a water bath for 10 minutes at 70°C (liquid temperature in the volumetric flask). The volumetric flask was removed and immediately cooled in ice water. After cooling, the palm sugar solution was added with 30% KI solution (10 mL) and 25% H_2SO_4 (25 mL). The addition of sulfuric acid is done carefully because CO_2 gas is formed. Palm sugar solution (10 mL) was put into a 500 mL Erlenmeyer flask with a lid and titrated with 0.1 N thiosulfate solution (a mL) using starch solution as indicator. Because the starch solution binds iodine, the starch solution is added when the titration is almost complete. Blanks were made as above procedure using Luff reagent (25 mL) and aquabidest (25 mL). The titration was carried out three times (triplo). Furthermore, the levels of glucose, fructose, and palm sugar inversion can be calculated from the difference between the two measurements above using the Luff Schoorl list (Baedhowie and Pranggonowati, 2020; Lubis *et al*., 2022; Pradnyana *et al*., 2014; Siregar and Maylia, 2017).

After Inversion

Palm sugar filtrate (50 mL) and 25% HCl (5 mL) and a few boiling stones were put into a 100 mL volumetric flask with a lid. The volumetric flask is connected to the reverse cooler and boiled in a water bath for 10 minutes at 70°C (liquid temperature in the volumetric flask). The volumetric flask was removed and immediately cooled in ice water. After cooling, the palm sugar solution is neutralized with 30% NaOH solution (phenolphthalein as an indicator) and diluted with aquabidest up to the mark line and shaken. Palm sugar solution (10 mL) was put into a 500 mL Erlenmeyer flask with a lid and titrated with 0.1 N thiosulfate solution (a mL) using phenolphthalein as an indicator. Blanks were made as above procedure using Luff reagent (25 mL) and aquabidest (25 mL). The titration was carried out three times (triplo). Furthermore, the levels of glucose, fructose, and palm sugar inversion can be calculated from the difference between the two measurements above using the Luff Schoorl list (Baedhowie and Pranggonowati, 2020; Lubis *et al*., 2022; Pradnyana *et al*., 2014; Siregar and Maylia, 2017).

Calculation

Palm sugar and sucrose levels at pH 3-7 (before and after inversion) can be calculated using equations (1) and (2) (Baedhowie and Pranggonowati, 2020; Lubis *et al*., 2022; Pradnyana *et al*., 2014; Siregar and Maylia, 2017).

$$\text{Sugar content (before and after inversion)} = \frac{\text{Nt x Fd}}{\text{Ws}} \text{ x } 100\% \qquad (1)$$

$$\text{Nt} = \text{Tb} - \text{Ts}$$

$$\text{Fd before inversion} = \frac{100}{50} \text{ x } \frac{250}{10} = 50$$

$$\text{Fd after inversion} = \frac{100}{50} \text{ x } \frac{250}{50} \text{ x } \frac{100}{10} = 100$$

$$\text{Sucrose Content} = [\text{Sucrose content after inversion } (\%) - \text{Sucrose content before inversion } (\%)] \text{ x } 0.95 \qquad (2)$$

Information:

Nt = Luff School table number

Tb = volume (mL) of 0.1 N thiosulfate solution for blank titration

Ts = volume (mL) of 0.1 N thiosulfate solution for sample titration

Fd = dilution factor

Ws = sample weight (mg).

Making Brown Sugar from Palm Sugar at pH 3-7

The palm sugar from tapping is filtered and the acidity level is adjusted (pH 3-7). Palm sugar (pH 3-7) is poured into a pan and heated on the stove at 90-100^{o}C. After the palm sugar boils, the stove is turned off and the palm sugar is allowed to stand for 30 minutes so that the fine impurities can precipitate together with the lime water to form calcium salts. The precipitate is separated from the palm sugar by filtering. Palm sugar (3.5 L) is put into a pan and then cooked on the stove at 115-120^{o}C for 1 hour. After the palm sugar begins to boil, the foam that appears on the surface together with fine dirt is immediately scooped up with a bamboo spoon. When foam bubbles overflowing from the palm sugar begin to appear, a bamboo cover is immediately attached to the edge of the pan to prevent the palm sugar from overflowing and to hold the dirt so that it adheres more to the bamboo sheet. Cooking is continued until the yellowish-white color of the palm sugar turns dark red and thick. At that moment, the bamboo sheet was removed from the edge of the wok. To speed up the thickening, one fine hazelnut seed is added to the palm sugar while stirring. To find out whether the concentrated palm sugar (gelali) is good enough to be printed into brown sugar, the following test is carried out. Jelly drops on the surface of cold water. If the sugar threads that form on the surface of the water break easily when you hold it, it means that the jelly is considered good enough. After that, the stove fire is reduced slowly and then turned off. The pan was immediately removed from the stove. The gelali is stirred while being crushed until it is thick like puddles. The jenang is immediately poured into a mold, the inside of which has been moistened beforehand so that the brown sugar does not stick to the base or walls of the mold when the brown sugar is dry and frozen. Brown sugar is removed from the mold and then wrapped in banana leaves or dry teak leaves. Brown sugar is stored in plastic jars to be tested for quality by quality determination panelists. Making brown sugar like the above procedure is carried out up to three times (triplo) for each change in pH or change in sucrose content of palm sugar (Ambarsari *et al.*, 2017; Arenga, 2023; Baharuddin *et al.*, 2023; Hasan *et al.*, 2020; Muchaymien *et al.*, 2014; Pontoh *et al.*, 2019; Radem and Rezekiah, 2015; Yuwono, 2015).

Organoleptic Quality Testing of Brown Sugar

The brown sugar samples (15 pieces) were labeled with the codes A, B, C, D, E, F, G, H, I, J, K, L, M, N, and O. The properties of the 15 brown sugar samples were tested characteristics of these materials which include: color, hardness, and taste. The quality determination panelists provide an assessment of the brown sugar samples presented with the following rating scale: (1). If it is reddish yellow, firm, and very sweet; (2) If it is brownish red, soft, and not sweet enough; (3) If it is blackish brown, tough, melts easily, sour and bitter.

The scales 1, 2, and 3 above also show the quality of brown sugar in categories 1 (high), 2 (moderate), and 3 (low) which can be distinguished based on their physical properties (Afrianti *et al.*, 2018; Han *et al.*, 2020; Herlina *et al.*, 2020; Indrawanto, 2020; Marsigit, 2005; Natawijaya and Suhartono, 2018; Nawansih *et al.*, 2022; Pontoh, 2013; Susanto and Subandi, 2018; Syahputra *et al.*, 2017).

Brown Sugar Quality Testing Based on SNI-01-3743-1995

The level of insoluble materials in the sample is determined using the filtering method (BSN, 1995). The sample (20 g) was put into a 400 mL beaker containing hot water (200 mL). The mixture is stirred until dissolved. When hot, the insoluble part is poured onto dried filter paper and weighed. The beaker and filter paper are rinsed with hot water. Then the filter paper was dried in an oven at 105 ^{o}C for 2 hours, cooled and weighed until a constant weight was obtained.

The water content in the sample was determined using the oven method (BSN, 1995). Empty aluminum cups were dried in an oven at 100 - 102 ^{o}C for 15 minutes and cooled in a desiccator for 10 minutes. Samples (5 g) were placed in a cup, then dried in an oven at a temperature of 100 - 102 ^{o}C for 6 hours. The sample and cup were cooled in a desiccator, weighed and dried again in the oven until a constant weight was obtained.

The ash content in the samples was determined using the kiln method (BSN, 1995). The ash cup before use is burned in a furnace, cooled in a desiccator and weighed. The sample (3-5 g) is weighed in a cup, then burned in a furnace at a temperature of 400 - 550 ^{o}C until the ash is white. The weight of the ash was weighed after it had cooled in a desiccator.

The levels of reducing sugar and sucrose in the samples were determined using the Luff Schoorl method such as the procedure for determining the sucrose content of palm sugar at pH 3-7 (Baedhowie and Pranggonowati, 2020; Lubis *et al*., 2022; Pradnyana *et al*., 2014; Siregar and Maylia, 2017).

Zinc (Zn) and copper (Cu) metal levels in the samples were determined using dry and wet digestion methods using atomic absorption spectrophotometry (AAS) (Manurung *et al*., 2016). Standard solutions of Zn^{2+} and Cu^{2+} 1000 ppm each were prepared by dissolving $ZnSO_4.7H_2O$ (0.4397 g) and $CuSO_4.5H_2O$ (0.4124 g) with aquabidest in a 100 mL volumetric flask. The Zn^{2+} and Cu^{2+} solutions were each diluted with 0.1 M HNO_3 to the limit mark.

Zn and Cu calibration curves were made by varying the concentrations of standard solutions of Zn (0, 1.0, 2.0, 4.0, and 6.0 ppm) and Cu (0, 0.2, 0.4, 0.8, 1.4, and 1.8 ppm), respectively. The absorbance of each concentration variation of the Zn and Cu standard solutions was measured by AAS at λ_{max} 213.88 nm and 324.72 nm, respectively.

Dry digestion was carried out by placing the sample (5 g) into a porcelain cup. The sample is heated over an electric bath gradually until the sample burns and no longer smokes. Heating the sample was continued in the furnace at a temperature of 500 °C until white ash was formed and was free from carbon. The white ash was dissolved in 6 N HCl (5 mL) and 0.1 M HNO_3 (5 mL) while heating on an electric bath for 2 - 3 minutes. The solution was put into a 50 mL volumetric flask and diluted with aquabidest to the mark. Next, the absorbance of the solution was measured with AAS at λ_{max} 213.88 nm for Zn metal and 324.72 nm for Cu metal. The metal concentrations of Zn and Cu in the sample were determined from the regression equation on the calibration curve of the standard solution for each metal (BSN, 1995).

Wet digestion was carried out by inserting the sample (5 g) into a 250 mL Erlenmeyer flask. The concentrated HNO_3 solution (15 mL) was added to the Erlenmeyer flask and left for 15 minutes. The solution is heated slowly in a fume cupboard until the remaining volume (1.5-3.0 mL) or before charcoal forms. The Erlenmeyer flask was removed from the heater and concentrated HCl solution (12.5 mL) was added. The solution was heated again until the remaining volume (5.0-7.5 mL). The solution was added with aquabidest (20 mL) then stirred and put into a 50 mL measuring flask. The solution was diluted with aquabidest to the limit mark. Next, the absorbance of the solution was measured with AAS at λ_{max} 213.88 nm for Zn metal and 324.72 nm for Cu metal. The metal concentrations of Zn and Cu in the sample were determined from the regression equation on the calibration curve of the standard solution for each metal (BSN, 1995).

RESULTS AND DISCUSSION

Results of Determination of Sugar Palm Sucrose Levels at pH 3-7 with the Luff Schoorl Method

Table 1 shows the results of determining the sucrose content of palm sugar at pH 3-7 using the Luff Schoorl method. Table 1 shows that the higher the pH of the palm sugar, the higher the sucrose content. This means that the lower the pH of the palm sugar, the lower the sucrose content. The level of acidity (pH) of palm sugar is directly related to its quality. The higher the pH of the palm sugar the higher the quality. Conversely, the lower the pH of the palm sugar the lower the quality (Anisum and Krisbiyantoro, 2023; Ansar, 2019; Arenga, 2023; Assah, 2020; Lukmana, 2021).

In 100 mL palm sugar (density 84°F = 1.02-1.03) contained sucrose (7.10 g), inversion sugar (0.15 g), reducing sugar (0.89 g), nitrogen (0.005 g), ash (0.021 g), and other substances (0.29 g) (Milsum and Dennett, 2019; Pontoh *et al*., 2019; Sarjani *et al*., 2023; Solang *et al*., 2020). The substance content of palm sugar like this allows microorganisms to grow and reproduce in it. Therefore, palm sugar as a result of tapping will easily be damaged by microorganisms so that the quality decreases.

Palm sugar damage can occur in biology and chemistry. Biological damage to palm sugar can be caused by the presence of microorganisms. Microorganisms that are usually mixed in palm sugar are bacteria, fungi, and yeast. There are three types of bacteria that commonly contaminate palm sugar, namely *Leuconostoc*, *Acetobacter* sp., and *Lactobacillus*. *Leuconostoc* bacteria can form profuse mucus. Bacteria *Acetobacter* sp. can turn alcohol into acetic acid. This change will occur quickly if the palm sugar contains about 10-13% alcohol. Other microorganisms that are active in the fermentation process are *Lactobacillus*. The results of this bacterial fermentation are in the form of impure acids, namely vinegar, lactic acid, ethanol, and carbon dioxide. Fermentation events like this are called heterofermentation, because several kinds of fermentation products are formed (Gottschalk, 2019).

There are three types of fungi that can contaminate palm sugar, namely *Rhizopus oryziae*, *Penicillium* sp., and *Aspergillus*. The fungus *Rhizopus oryziae* can cause palm sugar to become sour or alcoholic with a strong smell like bitter wine. Fungus *Penicillium* sp. can grow rapidly on the surface of the palm sugar to form floating blue colonies. The *Aspergillus* fungus can cause a change in the color of the palm sugar to brown. This is because this fungus grows and reproduces to form brown colonies that appear on the surface of the palm sugar (Paro, 2019).

Yeast is a single-celled microorganism and is easier to reproduce than bacteria and fungi. The type of yeast commonly found in palm sugar is *Saccharomyces* sp. The presence of yeast in palm sugar can cause changes in the sweet taste to sweet fresh and stimulating like alcohol. Palm sugar which already contains alcohol, in less than 12 hours can turn into acetic acid due to fermentation. Under these circumstances, the surface of the palm sugar is webbed. This membrane contains acetic acid bacteria called vinegar.

Palm sugar damage chemically can be caused by unfavorable storage conditions, the influence of oxidation, or the presence of chemical reactions from the compounds in the palm sugar. If the palm sugar is stored without any preservation efforts, then the palm sugar will spontaneously ferment. After the palm sugar is stored for 6-8 hours, the palm sugar will produce about 3% alcohol and 0.1% acetic acid. After that, the alcohol content will continue to increase to about 5%. Finally, the alcohol content will decrease and vice versa, the acid level will increase continuously until the fermentation reaction stops. This is what causes the lower the pH of the palm sugar the lower the quality because the sucrose content also decreases (Table 1).

Organoleptic Quality Test Results of Brown Sugar

Table 2 shows the results of organoleptic brown sugar quality testing.Table 2 shows that the pH and sucrose levels of palm sugar affect the quality of brown sugar. The lower the pH (3 and 4) and the sucrose content (11.30% and 12.25%) of the palm sugar, the lower the quality of the brown sugar produced. Conversely, the higher the pH (7) and the sucrose content (16.42%) of the palm sugar, the higher the quality of the brown sugar produced.

Table 2 also shows that the quality of palm sugar is determined by pH and sucrose content. This is because only sucrose can crystallize when palm sugar is heated. The crystalline form of sucrose in its pure state is the same as that of granulated sugar. The difference between granulated sugar and brown sugar is that in addition to sucrose, there is also inversion sugar (a mixture of D-glucose and D-fructose), protein, fat,

Table 1. The results of determining the sucrose content of palm sugar at pH 3-7 by Luff Schoorl

pH Palm sugar	Palm Sugar Sucrose Content (%)			
	Replication			Average
	1	2	3	
3	11.30	13.20	9.40	11.30
4	12.25	15.10	9.40	12.25
5	14.15	12.77	15.58	14.17
6	15.09	13.22	17.00	15.10
7	16.42	15.50	17.33	16.42

Table 2. Results of testing the quality of brown sugar organoleptic

Panelists	Brown Sugar Quality				
	Level of Acidity (pH) Palm Sugar				
	3	4	5	6	7
	Palm Sugar Sucrose Content (%)				
	11.30	12.25	14.17	15.10	16.42
1	3.0	3.0	1.3	2.0	1.0
2	3.0	3.0	1.3	2.0	1.0
3	3.0	2.7	2.0	2.0	1.0
4	3.0	2.7	1.0	2.0	1.3
5	3.0	3.0	1.3	2.0	1.0
6	3.0	3.0	1.7	2.0	1.0
7	2.7	2.7	1.0	2.0	1.7
8	3.0	2.3	1.3	2.0	1.3
9	3.0	3.0	2.0	2.0	1.0
10	3.0	2.7	1.7	2.0	1.0
11	3.0	3.0	2.0	2.0	1.0
12	3.0	3.0	1.3	2.0	1.0
13	2.7	2.7	2.0	1.0	1.3
14	3.0	2.7	2.0	2.0	1.0
15	3.0	3.0	2.0	2.0	1.0
16	3.0	3.0	1.3	2.0	1.0
17	3.0	3.0	1.7	1.0	1.0
18	3.0	3.0	1.3	2.0	1.0
19	2.7	3.0	2.0	2.0	1.0
20	2.7	3.0	1.3	2.0	1.0
21	3.0	2.7	2.0	2.0	1.0
22	2.3	3.0	1.3	2.0	1.0
23	2.7	3.0	2.0	2.0	1.0
24	3.0	1.3	1.7	2.7	1.3
25	2.0	2.7	2.0	2.7	1.0
26	3.0	3.0	1.7	1.0	1.0
27	3.0	3.0	2.0	2.0	1.0
28	2.3	3.0	1.3	2.0	1.0
29	2.7	2.7	2.0	2.0	1.0
30	3.0	3.0	2.0	2.0	1.0
Amount	85.8	84.9	49.5	58.4	31.9
Average	2.86	2.83	1.65	1.95	1.06
Rounding off	3	3	2	2	1
Category	Low	Low	Medium	Medium	High

and ashes (Milsum and Dennett, 2019). If palm sugar is heated directly, then some of these substances experience caramelization resulting in a change in the color of the substance from reddish yellow to blackish brown.

Fresh palm sugar has a pH of 5.5–7.0, tastes sweet, smells good, and is colorless. The sweet taste of palm sugar is caused by the presence of sucrose. Palm sugar with high sucrose content will produce high-quality brown sugar, which is hard, yellowish-red in color, and tastes sweet. Conversely, if palm sugar has a pH of 3.0–5.0 it will taste bitter, smell of vinegar, and have a white coating like milk. The bitter taste in palm sugar is caused by the presence of acetic acid. This indicates that the sucrose in the palm sugar has been fermented into acetic acid. If this fermented palm sugar is processed, it will produce low-quality brown sugar, which is tough, mushy, melts easily, tastes slightly sour and bitter, and the color is even darker to blackish brown.

If the palm sugar is allowed to stand without preservation, the pH of the palm sugar will decrease. The sweet taste of palm sugar began to change into a sour and bitter taste. Palm sugar that has a sour and bitter taste means that some of the sucrose has turned into acetic acid. The formation of acetic acid will lower the pH of the palm sugar. When the acidity level of the palm sugar reaches a pH below 5.0, boiling during the processing process will result in chemical damage to the palm sugar which is called an inversion event.

Sucrose inversion occurs in an acidic environment. If sucrose is hydrolyzed in an acidic environment, it will produce one molecule of D-glucose and one molecule of D-fructose. Rotation of the plane of polarization of light to the left of fructose (α = -92.4^o) is greater than the right rotation of glucose (α = +52.7^o). Therefore, in the hydrolysis of sucrose, the direction of rotation of the polarization plane changes from the right [sucrose, (α) = +66.5^o, positive rotation] to the left [fructose, (α) = -92.4^o, negative rotation] (Fessenden and Fessenden, 1986). This change in the direction of rotation of the plane of polarization of light is called an inversion. This mixture of hydrolyzed sugars is called inversion sugar. The enzymes that regulate this hydrolysis are called invertases (Figure 1). The chemical reactions that occur in the palm sugar during the fermentation are shown in Figure 1.

Results of Brown Sugar Quality Testing Based on SNI-01-3743-1995

Table 3 shows the results of brown sugar quality testing based on SNI-01-3743-1995. Table 3 shows that the shape, taste, aroma and color of brown sugar produced from palm sugar at pH 3–6 does not meet the requirements of SNI-01-3743-1995, while at pH 7 it meets the requirements of SNI-01-3743-1995. The clay, soft, and easily melted form of brown sugar is caused by the water content of brown sugar at pH 3 (13.95%), pH 4 (11.76%), pH 5 (9.58%), and pH 6 (7.36%) is quite high. Meanwhile, the hard and dense form of brown sugar is caused by the water content (3.25%) of brown sugar at pH 7 which is quite low. The sour, bitter, less sweet, vinegary and alcoholic taste of brown sugar is caused by the sucrose content of brown sugar at pH 3 (11.30%), pH 4 (12.25%), pH 5 (14.17%), and pH 6 (15.10%) is decreasing due to the sucrose in palm sugar being fermented to form alcohol and oxidized to form acetic acid (Figure 1). Meanwhile, the very sweet taste and distinctive smell of brown sugar is caused by the sucrose content of brown sugar at pH 7 (16.42%) which is quite high. This is because the sucrose in palm sugar at pH 7 has not been hydrolyzed to form inversion sugar (Figure 1). The blackish brown color of brown sugar is caused by the sucrose in palm sugar at pH 3 – 4 which has been hydrolyzed, fermented and oxidized to form acetic acid (Figure 1). The brownish red color of brown sugar is caused because the sucrose in palm sugar at pH 4 – 6 has been hydrolyzed and fermented to form alcohol (Figure 1). Meanwhile, the brownish yellow color of brown sugar is caused by the sucrose and inversion sugar in palm sugar at pH 7 experiencing caramelization during the heating process (Figure 1). This result is in accordance with statement of Ansar (2019), the brown color and distinctive taste of palm sugar is caused by the caramelization process.

Table 3 also shows that brown sugar produced from palm sugar at pH 3 and 4 respectively has water-insoluble ingredients of 1.54% and 1.26%. These results indicate that brown sugar produced from palm sugar at pH 3 and 4 does not meet the requirements of SNI-01-3743-1995 and is of low quality. Brown sugar produced from palm sugar at pH 5-7 respectively has water-insoluble ingredients of 0.97%, 0.73% and 0.58%. These results indicate that brown sugar produced from palm sugar at pH 5-7 meets the requirements of SNI-01-3743-1995 and is of medium and high quality. These results are in accordance with statement of Hartari (2016), that good quality brown sugar has a maximum of 1% insoluble solids, if it exceeds the existing standards it is called low quality. According to Fernando (2014), solids that do not dissolve in water come from non-sugar materials such as dirt brought in during processing or preservatives used, as well as other additives to increase the weight of brown sugar.

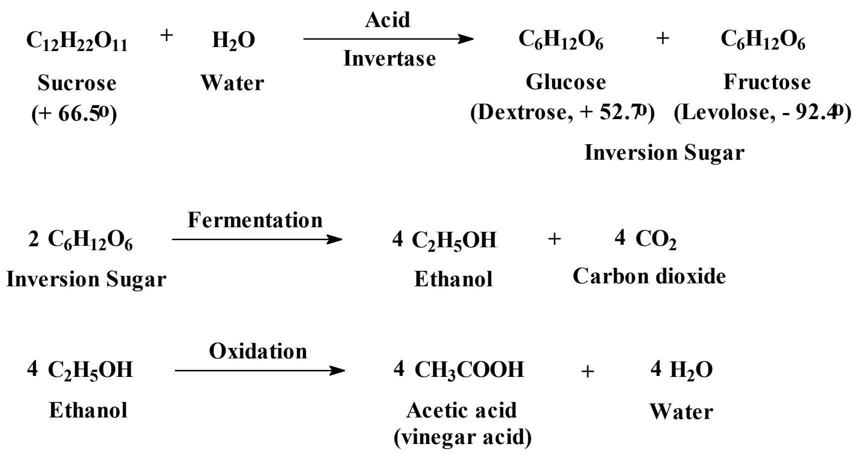

Figure 1. The decomposition reaction of sucrose into inversion sugar, ethanol, and acetic acid during palm sugar fermentation takes place (Gottschalk, 2019)

Table 3. Results of brown sugar quality testing based on SNI-01-3743-1995

No.	Test Criteria	Unit	SNI-01-3743-1995	Test results				
				Brown Sugar Quality				
				Low		Medium		High
				pH of Palm Sugar				
				3	4	5	6	7
1.	States							
1.1	Form		Normal	Clay, melts easily, not normal	Clay, melts easily, not normal	Soft, not normal	Soft, not normal	Hard, dense, normal
1.2	Taste and aroma		Normal, typical	Sour, bitter, vinegar smell	Sour, bitter, vinegar smell	Not sweet enough, smells of alcohol	Not sweet enough, smells of alcohol	Very sweet, distinctive fragrant smell
1.3	Color		Brownish yellow	Blackish brown	Blackish brown	Brownish red	Brownish red	Brownish yellow
2.	Material that is insoluble in water	% w/w	Max. 1,0	1.54	1.26	0.97	0.73	0.58
3.	Water	% w/w	Max. 10,0	13.95	11.76	9.58	7.36	3.25
4.	Ash	% w/w	Max. 2,0	2.58	2.17	1.53	1.08	0.87
5.	Reducing sugar	% w/w	Max. 10,0	3.19	3.45	5.75	5.31	1.35
6.	Sucrose	% w/w	Max. 77,0	11.30	12.25	14.17	15.10	16.42
7.	Metal contamination							
7.1	Zinc (Zn)	ppm	Max. 40,0	2.20	2.03	1.84	1.69	1.45
7.2	Copper (Cu)	ppm	Max. 2,0	1.36	1.15	0.93	0.71	0,52

Table 3 also shows that the water content of brown sugar produced from palm sugar at pH 3 and 4 does not meet the requirements of SNI-01-3743-1995, while at pH 5 - 7 it meets the requirements of SNI-01-3743-1995. The water content of brown sugar is influenced by the water content of palm sugar which is used as raw material for making brown sugar. The water content of palm sugar is influenced by seasonal conditions. During the dry season, the sap that comes out contains lower water content than during the rainy season (Dachlan, 1984). The water content of palm sugar is also influenced by the sucrose content. The lower the water content (3.25%) of palm sugar, the higher the sucrose content (16.42%). Conversely, the higher the water content (13.95%) of palm sugar, the lower the sucrose content (11.30%). This is related to the chemical reactions that occur in palm sugar (Figure 1). If the sucrose in palm sugar has not been hydrolyzed, fermented and oxidized to form acetic acid, the sucrose content of palm sugar is high (16.42%). Conversely, if the sucrose in palm sugar has been hydrolyzed, fermented and oxidized to form acetic acid, the sucrose content of palm sugar is low (11.30%).

Table 3 also shows that the ash content of brown sugar produced from palm sugar at pH 3 and 4 does not meet the requirements of SNI-01-3743-1995, while at pH 5-7 it meets the requirements of SNI-01-3743-1995. These results are in accordance with statement of Fernando (2014), that the ash content of brown sugar is influenced by solids that are insoluble in water. The higher the level of insoluble solids in water, the higher the ash content of brown sugar. Conversely, the lower the level of insoluble solids in water, the lower the ash content of brown sugar.

Table 3 also shows that the reducing sugar content of brown sugar produced from palm sugar at pH 3 - 7 meets the requirements of SNI-01-3743-1995. Reducing sugar is a carbohydrate that can be oxidized by Benedict's and Tollen's reagents. So, carbohydrates that give positive results when reacted with Benedict's and Tollen's reagents are called reducing sugars. The highest levels of reducing sugar are found in brown sugar produced from palm sugar at pH 5 (5.75%) and pH 6 (5.31%). This is because the sucrose in palm sugar at pH 5 and 6 has been hydrolyzed to form inversion sugar, namely one molecule of D-glucose and one molecule of D-fructose (Figure 1). The molecules of D-glucose (hemiacetal form) and D-fructose (hemiketal form) are reducing sugars because these two molecules give positive results when reacted with Benedict's or Tollen's reagents (Figure 2).

Table 3 also shows that the lowest reducing sugar content is found in brown sugar produced from palm sugar at pH 7 (1.35%). This is because the sucrose in palm sugar at pH 7 has not been hydrolyzed to form inversion sugar (Figure 1). Sucrose (acetal/ketal form) is a glycosides, a carbohydrate derivative in which the anomeric carbon is part of an acetal function. Sucrose is not a reducing sugar because this molecule does not give positive results when reacted with Benedict's or Tollen's reagents (Figure 3).

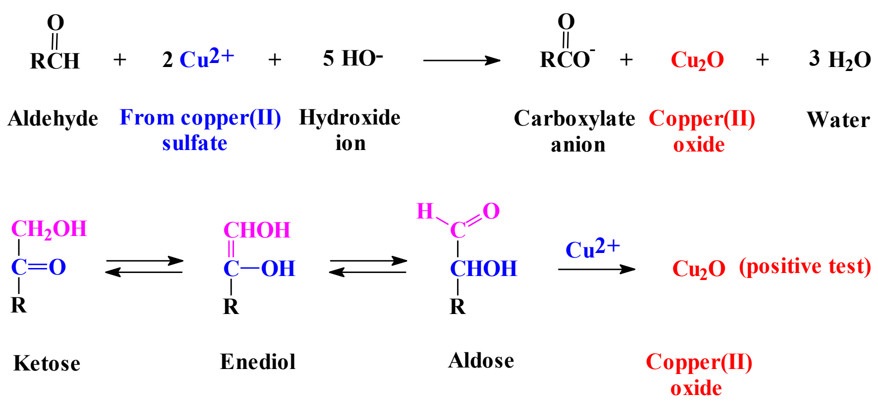

Figure 2. The formation of a red precipitate of copper(I) oxide by reduction of Cu(II) is taken as a positive test for an aldehyde and ketose (Carey, 1992)

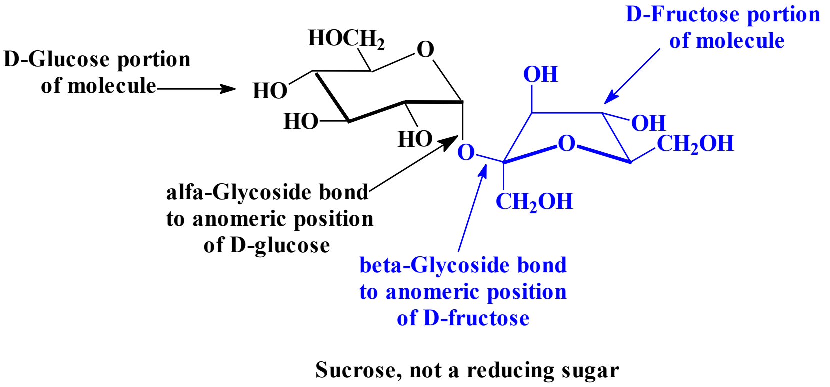

Figure 3. Sucrose (Carey, 1992)

Table 3 also shows that the sucrose content of brown sugar produced from palm sugar at pH 3 - 7 meets the requirements of SNI-01-3743-1995. The sucrose content of brown sugar is influenced by the pH of palm sugar. The higher the pH (7) of palm sugar, the higher the sucrose content (16.42%) of brown sugar. This is because at pH 7 the sucrose in palm sugar has not been hydrolyzed to form inversion sugar (Figure 1). Conversely, the lower the pH (3) of palm sugar, the lower the sucrose content (11.30%) of brown sugar. This is because at pH 3 the sucrose in palm sugar has been hydrolyzed, fermented and oxidized to form acetic acid (Figure 1). Table 3 also shows that the metal contamination levels of zinc (Zn) and copper (Cu) in brown sugar produced from palm sugar at pH 3 - 7 meet the requirements of SNI-01-3743-1995.

CONCLUSION

Palm sugar sucrose levels at pH (3, 4, 5, 6, and 7) were (11.30, 12.25, 14.17, 15.10 and 16.42%) respectively. The level of acidity (pH) and sucrose levels of palm sugar affect the quality of brown sugar. Palm sugar with sucrose content of 11.30% (pH 3) and 12.25% (pH 4) produces low quality brown sugar. Palm sugar with sucrose content of 14.17% (pH 5) and 15.10% (pH 6) produced medium quality brown sugar. Palm sugar with a sucrose content of 16.42% (pH 7) produces high quality brown sugar. So, the lower the pH and sucrose content of palm sugar, the lower the quality of the brown sugar produced. Conversely, the higher the pH and sucrose content of palm sugar, the higher the quality of the brown sugar produced. Therefore, the quality of palm sugar needs to be maintained so that the pH and sucrose content do not decrease so that the brown sugar produced is of high quality. The results of testing the quality of brown sugar based on SNI-01-3743-1995 show that brown sugar produced from palm sap at pH 5 – 7 meets SNI requirements. Meanwhile, brown sugar produced from palm sap at pH 3 and 4 does not meet SNI requirements.

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