Chemical Analysis of Arenga Palm Sugar and Its Relationship with Consumer Acceptability

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Abstract. In Indonesia, the quality of Arenga palm sugar must meet certain chemical component requirements, including water-insoluble material, water content, ash content, reducing sugar content, and sucrose content. The heating process of the sap water can affect the quality of the palm sugar, as well as the preferences of consumers because it affects sensory attributes. The aroma and taste of palm sugar are mainly influenced by the levels of reducing sugar and sucrose. The research objective is to determine the correlation between the chemical components of palm sugar and its consumer acceptance by comparing the data from different regions. The explanatory sequential method is used, which involves two tests for sensory analysis: the Check-All-That-Apply (CATA) test and the ANOVA test. The Pearson correlation method is used to analyze the correlation between palm sugar chemistry and customer acceptance. The research revealed that the water-insoluble material and sucrose content of palm sugar did not meet the Indonesian national standards (SNI). Sucrose sugar content is negatively correlated with the aroma of palm sugar, where the panelists' preference for palm sugar increased if the sucrose sugar content was lower.

1 Introduction

The natural food trend has had a significant impact on the food industry, with consumers worldwide showing a preference for natural food products [1-2]. Many consumers actively avoid food products they deem "unnatural," leading to a surge in demand for sweeteners made from natural sources in recent years [3]. One of these natural foods is arenga palm sugar. This sugar is produced from the sap of male flower bunches of palm trees, which is then heated until caramelization reaction [4]. Arenga palm sugar has a lower glycemic index and fewer calories compared to cane sugar, while also being more nutritious, making it an ideal choice for those seeking a healthier sweetener [5-6]. Consumers are willing to pay a premium price for this sugar, with prices ranging between Rp. 20,000 – Rp. 30,000 per kilogram, in contrast to cane sugar, which costs only Rp. 15,000 – Rp. 20,000 per kilogram as of 2023.

Palm sugar is considered a natural sweetener based on the natural food classification [1]. It is made from pure sap water and cooked using traditional utensils without any added food additives. The consumption of palm sugar has increased in Indonesia as consumers are looking for healthier lifestyles. This is a good opportunity for palm sugar producers in

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Indonesia, which have been struggling in many developing regions [7-8]. The processing of palm sugar is simple, using traditional cooking tools like firewood in an open processing area. This leads to a wide range of characteristics in the palm sugar produced and increases the potential for contamination with dangerous compounds.

To be competitive, palm sugar must meet quality standards and be safe for consumption. In Indonesia, palm sugar quality refers to SNI 3743-2021, which requires testing for chemical and sensory characteristics like water-insoluble ingredients, water content, ash content, reducing sugar content, sucrose content, and organoleptics [8]. The quality of palm sugar is influenced by the process of heating the sap water, which affects its flavor, sensory attributes, and consumer acceptance. Palm sugar flavor is the most prominent qualitative characteristic, which significantly influences consumer behavior and palm sugar consumption. The levels of reducing sugar and sucrose sugar in palm sugar affect qualitative and quantitative aspects, including aroma and taste [9].

To better understand the chemicals that provide palm sugar its desired sensory properties, it is necessary to gather information about its chemical levels, processes, and sensory attributes [10]. The Check-All-That-Apply (CATA) preference test and the Analysis of Variance (ANOVA) variability test are frequently used to to determine a product's placement among other products and identify samples that consumers prefer, [7]. Sensory analysis of the acceptance of palm sugar in the community is necessary to gather information on consumer preferences for palm sugar in a particular area compared to other palm sugar. The evaluation results can be used to determine the relationship between chemical analysis and customer acceptability [11].

Indonesia has emerged as a significant palm sugar exporter, with a growth rate of over 20%, which is more than three times the global average of 6%. The demand for palm sugar both domestically and internationally has reached 400 tonnes in the last decade [12]. Considering the significant growth of the palm sugar market, it is crucial to understand the factors that influence Indonesian consumers' preferences for palm sugar. Previous studies have focused on the characteristics of palm sugar, such as physicochemical properties, antioxidant activities, and volatile compounds [6], chemical characteristics [8], color changes during processing [13], phenolic analysis [14], and macro elements (sucrose, glucose and fructose) and micro elements (metal minerals) [15]. There has been limited research on chemical analysis and evaluates consumer acceptance of different sources of palm sugar in Indonesia. Palm sugar is produced in almost all regions of Indonesia, especially Sumatra, Java, Nusa Tenggara, and Sulawesi. The source Therefore, the objective of this study is to examine the relationship between the chemical components of palm sugar and consumer preference by comparing the results of chemical analysis and sensory evaluation data from various regions.

2 Methods

The research method used in this study is an explanatory sequential mixed method. This approach utilizes both quantitative and qualitative methods to investigate research questions. The method is divided into two separate phases, the first being the qualitative phase, and the second being the quantitative phase. The results of both phases are then combined to obtain a comprehensive understanding of the research problem [16]. The qualitative phase involves conducting in-depth interviews and field surveys. The quantitative phase involves analyzing the chemical characteristics and sensory properties of the samples. The data collected is then analyzed using XLSTAT, and Pearson correlation is used to determine any relationships between the data using SPSS. The results of the qualitative phase are then used to explain the results of the quantitative phase. The samples collected for analysis came from three different regions, and each sample was assigned a unique code based on its origin. The codes assigned were S1 (Kanekes, Banten), S2 (Menggala, North Lombok), and S3 (Probolinggo, East Java). Each sample was tested three times to ensure the validity of the results.

2.1 Analysis of chemical characteristics

The chemical analysis for palm sugar followed the requirements in SNI 3743-2021. It included the testing for water-insoluble ingredients, ash content, water content, reducing sugar, and sucrose content. The analysis was carried out at the Food Chemical laboratory located at the Collaborative STEM Laboratories building of Prasetiya Mulya University. The testing procedures followed SNI 01 2891-1992 for food and beverage.

2.2 Analysis of sensory characteristics

Sensory analysis is a method used to determine the preference and acceptance of a product using human senses. The analysis was conducted at the Food Sensory test laboratory located in the Collaborative STEM Laboratories building at Prasetiya Mulya University [17]. Each sample was presented in a random order. The sensory analysis was carried out on June 6 and 8, 2022, by 50 untrained panelists who met the following criteria: they were between 18-55 years old, lived in Jakarta or Tangerang, had consumed palm sugar, and were able to describe the attributes of a product.

In sensory analysis, there are two tests that can be used, 9-point hedonic scale test and the Check-All-That-Apply (CATA) test. The hedonic test was carried out to determine the level of panelists' preference for the samples. The CATA test is used to obtain more specific descriptive attributes that help in describing the sensory profile of palm sugar samples. To identify these attributes, a literature review was conducted, and results from focus group discussions in previous research were analyzed [8]. The results from these tests will be analyzed using XLSTAT and ANOVA. During the test, panelists are required to choose the attributes they perceive in the sample, rate their level of liking for each attribute, and assess their overall liking for the entire sample.

2.3 Analysis of correlation

In this research, data analysis of chemical and sensory characteristics was conducted using XLSTAT and SPSS. The CATA analysis tool consists of the Cochran's Q test, principal component analysis, and correspondence analysis. To determine the correlation between the chemical analysis of palm sugar and customer acceptability, the Pearson correlation method was employed. This statistical method enables us to study the relationship between a variable and other variable without questioning the dependence between them. The correlation coefficient, which measures the strength of the linear relationship between variables, was the result of the Pearson correlation. If the correlation coefficient value is 0, then there is no significant correlation between variables. On the other hand, if the correlation coefficient value is 1, then there is a significant influence between the variables [18]. The hypotheses tested in this research are Ho: r = 0 (there is no correlation between chemical analysis of palm sugar and customer acceptability) and H1: r ≠ 0 (there is a correlation between chemical analysis of palm sugar and customer acceptability). The study's significant level was 5%.

3 Results and discussion

3.1 Analysis of chemical characteristics

Impurities in the form of water-insoluble materials can affect the quality of palm sugar. These impurities are usually present in palm sap mixed with other ingredients like palm tree twigs, flowers, and preservatives. The level of water-insoluble ingredients is a good indicator of palm sugar quality. Low levels of water-insoluble ingredients indicate good quality palm sugar, while high levels indicate poor quality. Table 1 shows the results of the analysis. The analysis of water-insoluble materials indicates that samples S2 and S3 do not meet the quality requirements of SNI 3743:2021, as they exceed the standard with a maximum value of 1% w/w. The process used in producing sample S2 involves the use of grated coconut to give texture to palm sugar, which may be detected as a water-insoluble material. Both sample S1 and S3 do not use any additional ingredients. According to Elfriede [8], water-insoluble materials in palm sugar may be in the form of leaves entering the palm sap and going through a filtering process, as well as impurities from the tools used. Water-insoluble materials can be minimized by using filtration of palm sap with smaller pores, using clean tools, and ensuring that the ash from the burning firewood is not mixed during the palm sap heating process. To preserve the ash from burning firewood, the palm sap can be heated at a higher altitude, which reduces the ash content that rises when heating the palm sap.

Table 1. Results of analysis of chemical characteristics of palm sugar

Analysis	No. Sample*	Results (%b/b)	Standards (%b/b)
Water-Insoluble Material	S1	0,60 ± 0,00	Max. 1
	S2	3,30 ±0,02	
	S3	2,18 ± 0,07	
Ash Content	S1	1,68 ± 0,00	Max. 2,5
	S2	2,13 ± 0,07	
	S3	0,69 ± 0,04	
Water Content	S1	8,37 ± 0,00	Max. 10
	S2	7,17 ± 0,17	
	S3	7,22 ± 0,28	
Reducing Sugars	S1	0,56 ± 0,01	Max. 5
	S2	0,55 ± 0,03	
	S3	2,18 ± 0,26	
Sucrose Content	S1	85,78 ± 0,00	70-85
	S2	79,90 ± 0,00	
	S3	77,80 ± 0,00	

*S1 (Kanekes, Banten), S2 (Menggala, North Lombok) and S3 (Probolinggo, East Java)

Based on the results of the ash content test in Table 1, all samples meet SNI quality requirements, with a maximum value of 2.5% w/w. The ash content in palm sugar is related to the mineral content, both organic and inorganic salts, as well as the cleanliness of the processing process [19]. The mineral content in palm sap, which is the main ingredient for making palm sugar, greatly influences its ash content [8]. The difference in ash content in palm sugar can be attributed to the disparity in the mineral content of palm sap, which could depend on the habitat of palm trees [20]. Moreover, environmental conditions during production preparation, the production process, and high cooking temperatures could lead to high ash content. In addition, an unclean packaging process can leave organic and non-organic minerals in palm sugar, contributing to its high ash content.

The results of the water content test in Table 1 indicated that all three samples of palm sugar met the quality requirements in the SNI. The level of water content in palm sugar is influenced by various environmental factors, such as pH and temperature during preparation, cooking, packaging, shipping, and storage. The high water content found in palm sugar is due to its hygroscopic nature, which means it can easily absorb water vapor from the environment [8]. The texture of palm sugar is also affected by water content; the higher the water content, the softer the texture, and the easier it is for the sugar to absorb water [19]. To reduce the absorption of water vapor in palm sugar, it is important to pay attention to the handling and storage conditions, such as storing it in a dry place [21] and choosing vacuum packaging.

Reducing sugar is a type of sugar that contains an aldehyde group which can react with metals under alkaline conditions [22]. To determine the levels of reducing sugar, a colorimetric procedure is used, known as the Dinitrosalicylic acid (DNS) method. The results of the reducing sugar content test in Table 1 indicate that all samples meet SNI requirements. The data collected in this study is in the form of absorbance, which will be converted into reducing sugar concentration [23]. The level of reducing sugar can affect the color and texture of palm sugar. Higher levels of reducing sugar result in a more intense color and a hygroscopic and soft texture. To minimize the levels of reducing sugar, the heating time should be reduced as this inhibits the inversion process of sucrose into reducing sugar [8].

Based on the test results for sucrose content in Table 1, samples S2 and S3 meet the SNI requirements with a value of 70-85% w/w. However, sample S1 has a high sucrose content of 85.78%. This is because S1 has a high water content due to the short cooking process. In palm sugar, the levels of sucrose and reducing sugar are interrelated, as sucrose is subject to inversion at high temperatures during the heating process of palm sap. Inversion is a natural process where sucrose breaks down into glucose and fructose, which are reducing sugars. This process is catalyzed by enzymes released due to microbial activity in palm sugar. To minimize excessive sucrose levels, heating should be done for a longer time to allow the inversion process to occur and reduce excess sucrose levels to glucose and fructose.

3.2 Analysis of sensory characteristics

Attributes that have a p-value greater than 0.05 are clean sugar, dirty sugar, sweet aroma, licorice aroma, honey aroma, caramel aroma, light texture, honey taste, bitter aftertaste, astringent aftertaste, mouth drying aftertaste, licorice aftertaste, and palm sap aftertaste. This indicates that these attributes have no significant differences in each sample. Attributes that have a p-value smaller than 0.05 are light brown, medium brown, dark brown, palm sap aroma, sour aroma, bitter aroma, metallic aroma, sticky texture, thick texture, sandy texture, non-sandy texture, dry texture, sweet taste, bitter taste, caramel taste, metallic taste, sour taste, sweet aftertaste, and metallic aftertaste. This indicates that these attributes have significant differences. These differences can be considered real differences through correspondence analysis.

In Fig. 1 shows a symmetric plot of the results obtained from correspondence analysis. The quality of the analysis is considered to be quite good since it has a total inertia value of 85.25% in the first two dimensions, where the minimum good total inertia value is 70%. The symmetric plot reveals that sample S3 of palm sugar is very close to the ideal palm sugar. The ideal palm sugar is characterized by attributes such as a sweet taste, sweet aftertaste, caramel taste, thick texture, non-sandy texture, sticky texture, and medium brown color.

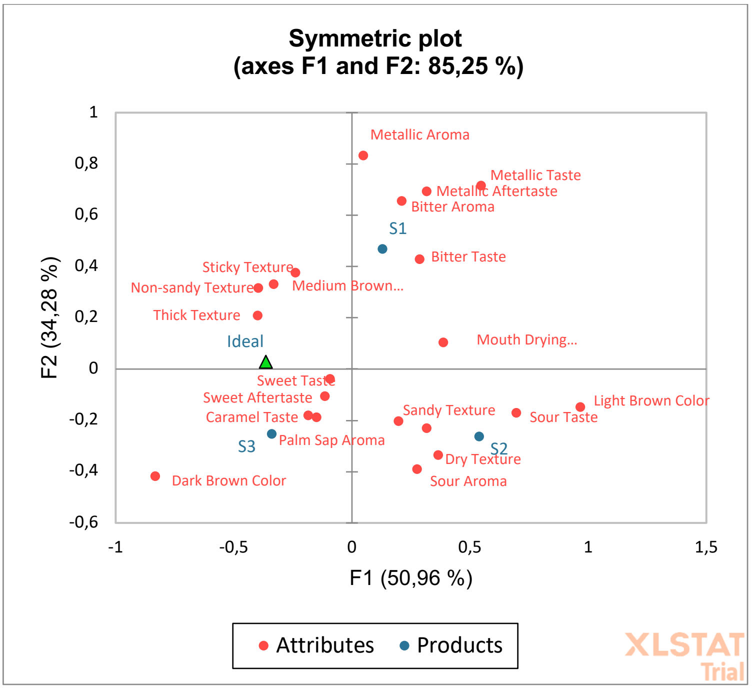

Fig. 1. Symmetric plot between samples and attributes

Good quality palm sugar has a high sugar content, which results in a sweet taste, caramel taste, and a sweet aftertaste. During the process of cooking palm sap, it is crucial to pay attention to the temperature and time that can affect the texture of palm sugar. Sample S3 is characterized by sweet taste, sweet aftertaste, caramel taste, palm sap aroma, and dark brown color. On the other hand, sample S2 is characterized by sandy texture, sour aftertaste, sour taste, light brown color, dry texture, and sour aroma. Lastly, sample S1 is characterized by metallic aroma, metallic taste, metallic aftertaste, bitter aroma, bitter taste, and mouth drying aftertaste.

Based on the results of the correspondence analysis, it can be concluded that sample S3 closely resembles the ideal characteristics of palm sugar. According to the panelists, the ideal palm sugar should have a sweet taste, sweet aftertaste, caramel taste, thick texture, non-sandy texture, sticky texture, and medium brown color. To produce ideal palm sugar, it is necessary to use quality palm sap that is dark brown in color and has a pH level of 6-8, as revealed by the interviews [6]. The caramel taste and brown color in palm sugar are the result of the caramelization reaction that occurs when palm sap is heated [24]. Additionally, to achieve a thick texture in the mouth, a sandy texture, and a sticky texture, it is recommended to add grated coconut, as suggested by one of the interviewees. Fig. 2 shows the principal component analysis, indicating that the attributes of sweet aftertaste, sweet taste, and caramel taste are closely associated with the level of consumer preference.

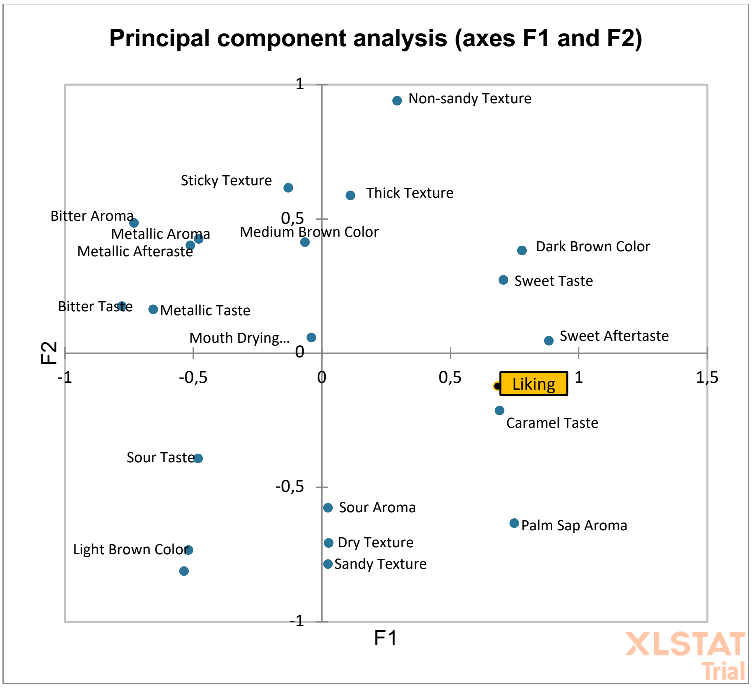

Fig. 2. Principal component analysis

Based on Table 2, it can be seen that the p-value for the panelists' preference ratings is less than 0.05 for the sample, appearance, aroma, texture, taste, and aftertaste attributes. This means that there are significant differences between the three samples of palm sugar. Therefore, it is necessary to conduct a Duncan analysis to compare the consumer preference levels for each sample, as shown in Table 3.

Table 2. Sum of square analysis (liking)

No. Sample	Mean	Standard error	Lower bound (95%)	Upper bound (95%)	Groups		
S3	7.760	0.160	7.603	8.237	A		
S2	7.220	0.160	6.903	7.537		B	
S1	6.440	0.160	6.123	6.757			C

During the test, panelists assessed various appearance attributes of palm sugar samples, including light brown color, medium brown color, dark brown color, clean palm sugar, and dirty palm sugar. The results revealed that sample S1 had a significant difference compared to samples S3 and S2 with mean values of 7,620 and 7,480 indicating “quite like”. In contrast, palm sugar sample S1 had a mean value of 5,880 representing “neutral”. The reason for this difference in panelist preferences is associated with the light brown color of sample S1. According to the panelists, the light brown color does not indicate ideal palm sugar, which explains why these samples have different preferences in terms of appearance.

The panelists evaluated various aroma attributes, such as sugar palm, sour, sweet, bitter, metallic, licorice, honey, and caramel, and rated their level of liking for each sample's aroma. The results showed that sample S1 differs significantly from samples S3 and S2 with mean values of 7.3 and 7.040 representing "quite like". Meanwhile, the average score for palm sugar was 6, indicating that panelists only “slightly liked” its aroma attributes. This is because palm sugar is associated with metallic and bitter aromas, which the panelists did not find appealing.

Table 3. Summary all pairwise comparison of sample

Category	**No. Sample**	**Mean**	**Standard error**	**Lower bound (95%)**	**Upper bound (95%)**	**Groups**		
Appearance	S3	7.620	0.202	7.221	8.019	A		
	S2	7.480	0.202	7.081	7.879	A		
	S1	5.880	0.202	5.481	6.279		B	
Aroma	S3	7.300	0.196	6.913	7.687	A		
	S2	7.040	0.196	6.653	7.427	A		
	S1	6.000	0.196	5.613	6.387		B	
Texture	S3	7.600	0.196	7.212	7.988	A		
	S2	7.180	0.196	6.792	7.568	A		
	S1	6.460	0.196	6.072	6.848		B	
Taste	S3	7.780	0.228	7.329	8.231	A		
	S2	6.820	0.228	6.369	7.271		B	
	S1	6.240	0.228	5.789	6.691		B	
Aftertaste	S3	7.460	0.214	7.037	7.883	A		
	S2	6.920	0.214	6.497	7.343	A		
	S1	5.980	0.214	5.557	6.403		B	
Overall Liking	S3	7.760	0.160	7.603	8.237	A		
	S2	7.220	0.160	6.903	7.537		B	
	S1	6.440	0.160	6.123	6.757			**C**

During the evaluation process, the panelists assessed different texture attributes of the samples. These included sticky texture, light texture, thick texture, sandy texture, not sandy texture, and dry texture. Sample S1 was found to be significantly different from samples S3 and S2, with mean values of 7.6 and 7.18 representing "quite like". However, the panelists found the texture of sample S1 to be slightly less desirable, with mean value of 6.46 representing " slightly liked". The panelists enjoyed the texture of palm sugar samples S3 and S2 the most because they were similar to ideal palm sugar texture. Additionally, sample S2 contained grated coconut which gave it a thick texture.

The panelists assessed various taste attributes such as sweet, bitter, honey, caramel, metallic, and sour tastes. Among the three samples, S3 has a significant difference from S2 and S1 samples. Sample S3 has a mean value of 7.78, indicating “quite like” towards palm sugar, whereas the mean value for samples S2 and S1 is 6.82 and 6.24 indicating “slightly liked” towards palm sugar. The symmetric plot suggests that S3 palm sugar has similar taste characteristics to the ideal palm sugar, especially sweetness and caramel taste.

During the evaluation, the panelists assessed various aftertaste attributes such as bitter, sweet, sour, sweet astringent, bitter, honey, caramel, metallic, and sour. It was found that sample S1 had a significant difference compared to samples S3 and S2, with a mean value of 5.98, representing "neutral" taste. According to the symmetric plot, palm sugar S1 had a metallic aftertaste and a mouth drying aftertaste, which was not preferred by the panelists. On the other hand, palm sugar samples S3 and S2 were associated with a sweet and slightly sour aftertaste, which the panelists liked.

The level of liking for each sample among the panelists was significantly different. This was evident from the grouping of each palm sugar sample. The palm sugar sample with a number of S3 was in group A with a mean value of 7.769, indicating that it was "quite liked". The sample S2 was in group B with a mean value of 7.220, which also represented "quite like". The sample S1 was grouped in C with a mean value of 6.440, indicating "slightly liked”. Overall, the panelists found that they quite liked palm sugar from these three regions.

3.3 Analysis of correlation

The results of the correlation analysis between chemical characteristics and customer acceptability are presented in Table 4. According to the analysis, there is a significant relationship between sucrose sugar content and the panelists' preference for aroma attributes at a significance level of 0.042. This relationship is reflected in the Pearson coefficient of -0.998. The minus value in the Pearson coefficient indicates a relationship, if the sucrose sugar content decreases, the panelists' level of preference for the aroma attribute will be higher. Other chemical characteristics do not show significant correlation with customer acceptability. They have a significance level greater than 0.05.

This will cause the quality of the sugar obtained to vary as well. A pH that is too acidic or too alkaline can not only affect the aroma of the sugar, but can also result in failure in the processing process. Therefore, it is necessary to heat for a longer time to inhibit the growth of microorganisms. This process can remove the aroma of alcohol and acid, thus producing a distinctive aroma of palm sap that panelists like [25]. This is in accordance with the results of the correlation analysis where the lower the sucrose sugar content, the higher the level of panelists' preference for the aroma attribute.

The longer the heating process, the more the sucrose sugar in the sap is converted into reducing sugar and the less sucrose is produced. Beside that, a higher heating temperature will produce a better aroma. Heating also helps prevent the growth of microorganisms in the sap, which can convert sucrose into glucose and fructose, leading to fermentation and the production of ethanol and acetic acid [25]. To prevent this, farmers must ensure that their harvesting equipment is clean, maintain proper tapping techniques and keep a sufficient distance between the trees and the production house [26]. The quality of sugar can vary depending on these factors including pH levels which can affect its aroma and processing. Heating process will remove the aroma of alcohol and acid and produce a distinct aroma that panelists prefer [25]. This is supported by the results of a correlation analysis, which shows that the lower the sucrose content, the higher the preference of panelists for the aroma attribute.

Table 4. Result of correlation analysis

	Sensory Analysis	**Overall Liking**	**Appearance**	**Aroma**	**Texture**	**Taste**	**Aftertaste**
Chemical Analysis							
Water-Insoluble Material	Pearson Correlation	0.593	0.878	0.816	0.697	0.461	0.700
	Sig. (2-tailed)	0.596	0.319	0.393	0.509	0.695	0.506
Ash Content	Pearson Correlation	-0.667	-0.289	-0.400	-0.560	-0.775	-0.556
	Sig. (2-tailed)	0.535	0.813	0.738	0.622	0.436	0.625
Water Content	Pearson Correlation	-0.860	-0.995	-0.977	-0.922	-0.771	-0.923
	Sig. (2-tailed)	0.43	0.062	0.137	0.254	0.440	0.251
Reducing Sugar	Pearson Correlation	0.855	0.555	0.649	0.776	0.925	0.774
	Sig. (2-tailed)	0.348	0.626	0.551	0.434	0.248	0.437
Sucrose Content	Pearson Correlation	-0.968	-0.983	-0.998	0.925	-0.918	-0.994
	Sig. (2-tailed)	0.161	0.117	0.042*	0.248	0.260	0.071

*Significance level <0.05

4 Conclusion

Based on the research carried out, it can be indicated that an ideal palm sugar should have certain characteristics, including a sweet taste, sweet aftertaste, caramel taste, thick texture, and a medium brown color. According to the symmetric plot, palm sugar S3 is very similarly to ideal palm sugar. Furthermore, the results of the principal component analysis show that panelists preferred sweet aftertaste, sweet taste, and caramel taste attributes. Panelists quite liked palm sugar S3 and S2, and slightly liked palm sugar S1. The correlation analysis revealed a relationship between sucrose sugar content and panelists' preference for aroma attributes. A decrease in sucrose sugar content leads to an increase in the level of preference for aroma attributes among panelists.

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