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Technique engineering of tapping and shelter of coconut sap and its effect on the quality of crystal coconut sugar

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Abstract

This study was aimed to examine the appropriate and effective techniques for tapping and sheltering coconut sap to produce quality crystal coconut sugar products according to SNI 3743-2021 for palm sugar. The research was conducted using an experimental method with a non-factorial randomized block design (RBD) of 14 different tapping and shelter treatments. The physicochemical parameters of crystal coconut sugar that were observed were moisture content, ash content, sucrose and reducing sugar content. The statistical analysis of data using the ANOVA test (F test), DMRT α 5% test and the Effectiveness Index Test. The results showed the five best methods for tapping and sheltering coconut sap that could produce crystal coconut sugar products with quality levels of sucrose, reducing sugar, moisture and ash content according to SNI 3743-2021, respectively are methods VII, V, VIII, VI and I. Method VII was tapping in from the afternoon to night for 8 hrs (14.00 AM-22.00 PM), + 2% laru (natural preservative), without heating and shelter duration or being processed directly into crystal coconut sugar. Method V was tapping in the morning to noon for 8 hrs (06.00-14.00 AM), + 2% laru (natural preservative), without heating shelter duration. Method VIII was tapping afternoon to night for 8 hrs (14.00 AM-22.00 PM), + 2% laru (natural preservative), without heating, and shelter duration for 3 hrs. Method VI was tapping in the morning to noon for 8 hrs (06.00-14.00 AM), + 2% laru (natural preservative), without heating and shelter duration for 3 hrs. Method I was tapping in the morning to noon for 6 hrs (06.00-12.00 AM), without laru (natural preservative), without heating and shelter duration or being processed directly into crystal coconut sugar.

1. Introduction

The quality of coconut sugar is determined by several factors, including the quality of the raw material (coconut sap). The quality of coconut sap as the main raw material for coconut sugar is strongly influenced by several factors such as the variety and age of the coconut trees, weather conditions (temperature, humidity, rainfall), heat/solar radiation, altitude, soil conditions (soil type and fertility), harvest handling process (tapping) and post-harvest (storage and transportation) and processing unit (factory).

Harvest and post-harvest handling techniques or methods, especially at the stage of tapping coconut sap (harvesting), shelter, and transporting of coconut sap from the coconut plantation to the processing unit (factory) have an important role in producing good quality coconut sap and crystal coconut sugar products. The results of Haryanti *et al*. (2017) and Mustaufik *et al*. (2020) show that the time and duration of tapping have a significant effect on changes in the quality of coconut sap. Tapping time that is too long (more than 8 hrs) will cause a decrease in the quality of coconut sap, especially the pH and sucrose content due to the fermentation process of coconut sap. The optimal tapping time to maintain the quality of sap from morning to noon without the addition of natural preservative ("laru") is 6 hrs (06.00 AM-12.00 AM) and with the addition of

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natural preservative ("laru") is 8 hrs (06.00 AM-02.00 PM). The optimal time for tapping coconut sap from the afternoon to night to maintain the quality of coconut sap without the addition of "laru" is 8 hrs (02.00 PM-10.00 PM) and with the addition of "laru" is 10 hrs (2.00 PM-12.00 AM). The results of Mustaufik *et al*. (2020) also showed that the addition of "laru" and heating at 95°C of coconut sap at the shelter stage was able to maintain the quality of coconut sap for 3-6 hrs with a pH still around 6-7 and a sucrose content around 16 – 17%.

The quality of coconut sap from harvest and post-harvest handling which is carried out by engineering different tapping and shelter techniques of coconut sap will certainly determine the quality of the crystal coconut sugar products produced. Detailed studies or research related to tapping time and duration, shelter time and duration, as well as the effectiveness of providing preservative coconut sap ("laru") and heating coconut sap during the shelter time, have not been widely carried out. Based on this, it is necessary to study the appropriate technique or method of tapping and shelter coconut sap to be able to produce crystal coconut sugar products with quality according to SNI 3743 – 2021.

This study was aimed to find the right time and duration of tapping, as well as the effective application of a natural preservative ("laru"), heating and shelter duration for coconut sap to produce crystal coconut sugar products with the appropriate quality of SNI 3743-2021.

2. Materials and methods

2.1 Time and place

This research was conducted in August-September 2019 in the coconut plantation of Gandatapa Village, Kembaran District, Banyumas Regency. The location of the coconut plantation has an altitude of about 525 m above sea level with an average rainfall of 104-107 mm and an average temperature ranging from 24.1-35.3°C and average humidity of 43.8-87.0%.

2.2 Materials and tools

The main ingredient of this research is coconut sap which is obtained from tapping and storage using different techniques. The coconut sap is then processed into crystal coconut sugar using the same process and technique (SOP). Additional ingredients included are laru as a natural preservative (a mixture of lime solution and mangosteen peel extract), and chemicals for the analysis of reducing sugars, sucrose sugars and total sugars, such as 0.5% starch solution, 25% H_2SO_4 solution, 20% KI solution, 10% $NH_4H_2PO_4$, 0.1 N $Na_2S_2O_3$ solution, half-alkaline lead acetate solution, and luff schoorl solution.

The tool used to measure the physicochemical properties of coconut sap is a pH meter Pen Type PH-009-A (acidity level), Refractometer Bx ATC-KW0600748 (total dissolved solids), digital Bx Refractometer Hanna series H196801 (sucrose content), Hygrometer, and temperature data logger series USB Elitech RC4. The tools used to measure the physicochemical properties of crystal coconut sugar such as furnace (moisture and ash content), spectrophotometry (sucrose and reducing sugar content), 50 mL glass burette, round bottom flask, analytical balance, 100 mL and 250 mL volumetric flask, electric heating, 10 mL, 25 mL and 50 mL volumetric drop pipette.

2.3 Experimental design

The research was conducted using an experimental method with a single factor (nonfactorial) randomized block design (RBD) consisting of 14 factors of treatment methods/techniques of tapping and storage of coconut sap with 3 replications to obtain 42 experimental units. 14 methods/techniques of tapping and shelter of coconut sap were tried as followed:

Method I: tapping time from morning to noon for 6 hrs (06.00 AM-12.00 PM), without laru, heating, sheltered duration or directly produced into crystal coconut sugar.

Method II: tapping time from morning to noon 6 hrs (06.00 AM-12.00 AM), without laru, heated at 95°C, sheltered duration for 3 hrs then produced into crystal coconut sugar.

Method III: tapping time from noon to night for 8 hrs (12.00 PM-08.00 PM), without laru, heating, sheltered duration or being directly produced into crystal coconut sugar.

Method IV: time tapping from noon to night for 8 hrs (12.00 PM-08.00 PM), without laru, heating at 95°C, sheltered duration for 3 hrs then produced into crystal coconut sugar.

Method V: tapping time from morning to noon for 8 hrs (06.00 AM-02.00 PM), + 2% laru, without heating, sheltered duration or directly produced into crystal coconut sugar.

Method VI: tapping time from morning to noon for 8 hrs (06.00 AM-02.00 PM), + 2% laru, without heating, sheltered duration for 3 hrs and then produced into crystal coconut sugar.

Method VII: tapping time from afternoon to night for 8 hrs (02.00 PM-10.00 PM), + 2% fresh, without heating, without shelter duration or directly produced into crystal coconut sugar.

Method VIII: tapping time from afternoon to night for 8 hrs (02.00 PM-10.00 PM), + 2% laru, without heating, shelter duration for 3 hrs, then produced into crystal coconut sugar.

Method IX: tapping time from morning to noon for 8 hrs (06.00 AM-02.00 PM) + 2% laru, heated at 95°C, shelter duration for 3 hrs then produced into crystal coconut sugar.

Method X: Tapping time from morning to noon for 8 hrs (06.00 AM-02.00 PM), + 2% laru, heating 95°C, shelter duration for 6 hrs then produced into crystal coconut sugar.

Method XI: Tapping time from afternoon to night for 8 hrs (02.00 PM-10.00 PM), + 2% laru, heating 95°C, shelter duration for 6 hrs and then produced into crystal coconut sugar.

Method XII: Time tapping in the afternoon to night for 8 hrs (02.00 PM-10.00 PM), + 2% laru, heating 95°C, shelter duration for 12 hrs then produced into crystal coconut sugar.

Method XIII: Tapping time from morning to noon for 6 hrs (06.00 AM-12.00 PM), without laru, heating at 95°C, shelter duration for 6 hrs and then produced into crystal coconut sugar.

Method XIV: Time tapping from noon to night for 8 hrs (12.00 PM-08.00 PM), without laru, heating at 95°C, shelter duration for 6 hrs then produced into crystal coconut sugar.

2.4 Observation and data analysis

Physical quality parameters of crystal coconut sugar observed in this study include moisture and ash content using the oven method (AOAC, 2005), total sugar content using the phenol method, sucrose sugar content using the Luff Schoorl method and reducing sugar content using the DNS method (Sudarmadji *et al*., 1997).

Statistical analysis of data using the ANOVA test (F test) and DMRT α 5% test (Gomez, 1995). Furthermore, to select the technique/method of tapping and shelter coconut sap that can produce the best crystal coconut sugar products, statistical analysis of the Effectiveness Index Test was used (De Garmo *et al*.,1984).

3. Results and discussion

Based on the results of the observational test, the physicochemical characteristics (pH, total dissolved solids and sucrose levels) were obtained from the coconut sap as a result of handling with different tapping and shelter methods as follows, see Table 1.

Based on Table 1, it is known that different tapping and shelter methods will result in different physicochemical qualities, especially pH, total dissolved solids and sucrose levels of coconut sap. It can be seen that method VII, its tapping time from afternoon to night for 8 hrs (02.00 PM-10.00 PM) with the addition of 2% laru and without shelter duration or immediately being processed into crystal coconut sugar gives improves the coconut sap physicochemical quality with a pH of 8.13, total dissolved solids 18.72°Bx and sucrose content of 17.52%, then followed by method V which was conducted for 8 hrs (06.00 AM-02.00 PM), with an addition of 2% laru and without shelter duration was found with pH 7.14, total dissolved solids 18.49°Bx and sucrose content 17.29%. Applying 2% laru and heating of coconut sap at the shelter stage is effective enough to maintain the physicochemical quality, especially the pH and sugar content of coconut sap for a maximum of 3 hrs. If the shelter period is more than 3 hrs (> 6 hrs), the physicochemical quality of coconut sap sharply decreases. The pH drops from 8 to 4 and sucrose drops from 17% to 15%.

Table 1. Observation of the physicochemical characteristics (pH, total dissolved solids, and sucrose content) of coconut sap as a result of handling with different tapping and shelter methods

Tapping and shelter methods of coconut sap	Physicochemical characteristics of Coconut		
	pH	Total dissolved solids (°Bx)	Sucrose content (%)
Method I	5.56	16.23	15.93
Method II	5.32	16.66	15.26
Method III	7.19	16.78	15.28
Method IV	7.26	16.95	15.95
Method V	7.14	18.49	17.29
Method VI	6.39	17.82	16.6
Method VII	8.13	18.72	17.52
Method VIII	7.33	17.43	16.93
Method IX	5.79	16.58	15.28
Method X	5.03	16.54	15.34
Method XI	5.39	16.65	15.75
Method XII	4.73	16.29	15.09
Method XIII	4.62	16.35	15.14
Method XIV	4.31	16.04	15.12

The results displayed the stronger effects of laru compared to the heating effect in maintaining the pH and coconut sap sucrose during the shelter process. This is because laru is an alkaline, soluble and antimicrobial substance (Naufalin *et al*. 2012). Laru in coconut sap can inhibit the fermentation of coconut sap optimally for a long time (8-11 hrs), while heating only affects microbial inactivity but does not have an impact on pH and the effect only lasts briefly when the sap is still at high temperature (60-95°C), but when the sap returns to room

temperature (27-28°C), the coconut sap can re-undergo fermentation during shelter.

The results of the observation and analysis of the DMRT test for physicochemical characteristics (moisture content, sucrose content, reducing sugar content and ash content) crystal coconut sugar produced from coconut sap handled by different tapping and shelter methods, are presented in Table 2.

3.1 The moisture content

The results of the analysis (F test) in Table 3 show that different methods of tapping and sheltering coconut sap have a significant effect on the moisture content of crystal coconut sugar products. Based on the results of the DMRT test (Table 2), it is known that the average water content of coconut crystal sugar products from the research results ranges from 2.92-6.75%. The lowest water content of crystalline coconut sugar (<3%) is produced from coconut sap which is handled using the tapping and holding methods VII, VIII. IX, V and I. The moisture content of crystal coconut sugar <3% of the production with this method of handling coconut sap is in accordance with SNI 3743-2021 standards, is maximum of 3% (National Standardization Agency, 2021). The method of handling coconut sap with a tapping duration of 6-8 hrs, applying 2% laru and without shelter time (directly processed into crystal coconut sugar), is able to maintain the quality of coconut sap because it does not undergo fermentation, resulting in low moisture content and high sugar content, as shown in Figure 1.

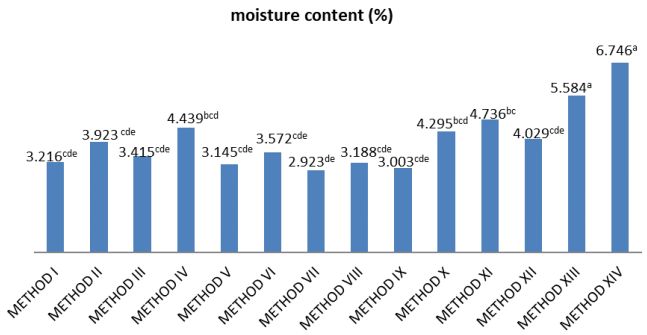

Figure 1. Average moisture content of crystal coconut sugar produced from coconut sap with different tapping and shelter methods. Data labels present the mean values of treatment. Data labels with different superscript are significantly different based on DMRT α 5% test.

Table 3. ANOVA test (F test) results the effect of coconut sap tapping and shelter methods on the moisture content of crystal coconut sugar

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
Treatment	13	50.971	3.920	5.84	<.0001 *
Block	2	0.314	0.157	0.23	0.792

*significant at α = 0.05

The highest average moisture content (4.7-6.75%) is shown by crystal coconut sugar produced from coconut sap handled with methods IV, X, XI, XII, XIII, and XIV. These methods were conducted within more than 8 hrs, with a sheltering duration of more than 3 hrs, without laru and the heating of coconut sap. This is because this method is not able to maintain the quality of coconut sap from deterioration or quality damage due to factors such as excessive tapping time, the absence of treatment to

Table 2. DMRT test results for mean physicochemical quality of crystal coconut sugar produced from coconut sap using different tapping and shelter methods

Tapping and shelter methods of coconut sap	Physicochemical quality of crystal coconut sugar			
	Moisture content (%)	Sucrose content (%)	Reducing sugar content (%)	Ash content (%)
Method I	3.216^{cde}	72.916^{e}	4.757^{cd}	1.981^{a}
Method II	3.923^{cde}	66.574^{f}	5.511^{b}	1.862^{ab}
Method III	3.415^{cde}	76.437^{d}	5.904^{b}	1.772^{ab}
Method IV	4.439^{bcd}	67.561^{f}	5.094^{bc}	1.673^{ab}
Method V	3.145^{cde}	82.428^{c}	2.667^{de}	1.718^{ab}
Method VI	3.572^{cde}	81.164^{c}	2.503^{e}	1.853^{b}
Method VII	2.923^{de}	91.508^{a}	2.241^{e}	1.694^{ab}
Method VIII	3.188^{cde}	86.577^{b}	2.887^{de}	1.785^{ab}
Method IX	3.003^{cde}	62.618^{g}	5.258^{bc}	1.494^{b}
Method X	4.295^{bcd}	71.590^{e}	5.605^{b}	1.988^{a}
Method XI	4.736^{bc}	71.697^{e}	2.378^{e}	1.803^{ab}
Method XII	4.029^{cde}	62.571^{g}	2.505^{e}	1.896^{ab}
Method XIII	5.584^{a}	65.378^{f}	5.040^{bc}	1.774^{ab}
Method XIV	6.746^{a}	48.352^{h}	7.437^{a}	1.712^{ab}
SNI 3743-2021 (%)	Max.3.0	80-90	Max.3.0	Max.2.5

Values are presented as mean value of treatment. Values with different superscript within the same column are significantly different based on DMRT α 5% test.

reduce the rate of fermentation (such as the addition of laru and heating) or because of excessive shelter time (more than 3 hrs). The high rate of fermentation results in the high-water content of coconut sap as a result of the reduction of sucrose sugar into ethyl alcohol and water, compared to crystal coconut sugar handled by methods VII, VIII and V. This phenomenon is in accordance with the opinion of Karseno *et al*. (2018), which states that the process of decaying sap begins with the invertation process which converts sucrose to glucose and fructose to ethanol and CO_2, ending with transforming ethanol to acetic acid and water. Based on the test results and analysis above, to produce a lower moisture content of crystal coconut sugar (<3%,) the appropriate and effective tapping and shelter technique for coconut sap is 6-8 hrs of tapping, applying laru (natural preservatives) and without shelter duration, and immediately processing it into crystal coconut sugar.

3.2 The reduction sugar content

The results of the analysis (F test) in Table 4 show that the different tapping and shelter methods of coconut sap have a significant effect on the reducing sugar content of crystal coconut sugar. The DMRT test results (Table 2) show that the lowest reducing sugar content (2.2-2.5%) is was by crystal coconut sugar produced from methods VII, XI, and XII, then followed by methods V, and VIII with a reducing sugar content ranging from 2.6 to 2.8%. The reduced sugar content of crystal coconut sugar as a result of this study is in accordance with the standard quality standards of SNI 3743-2021 which are stipulated by National Standardization Agency,which requires a standard of good crystal coconut sugar reduction content is a maximum of 3.0% (National Standardization Agency, 2021).

Table 4. ANOVA test (F test) results the effect of different tapping and shelter method of coconut sap on reducing sugar content of crystal coconut sugar

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
Treatment	13	107.761	8.289	15.30	<.0001 *
Block	2	0.647	0.323	0.60	0.557

*significant at α = 0.05

The low levels of reducing sugar in crystal coconut sugar by the above methods are strongly suspected to be due to the quality of coconut sap handled from 6-8 hrs with the addition of 2% laru, heating treatment and shelter duration for 3-6 hrs. The jam turned out to be able to control the fermentation rate of coconut sap, especially the rate of investment process or the reduction of sucrose sugar into reducing sugar. This is in accordance with the research results of Haryanti *et al*. (2017), that the addition of laru can prevent the rate of reduction process of coconut sugar.

The average highest reducing sugar content (7.74%) is found in the coconut sugar produced by the XIV method, tapping for 8 hrs from 12.00 PM-08.00 PM, without laru, followed by heating at 95°C and sheltered duration for 6 hrs. The reducing sugar content of the crystal coconut sugar produced by the XIV method exceeds the quality standard limits set by SNI 3743-2021, which is a maximum of 3% (National Standardization Agency, 2021), as shown in Figure 2.

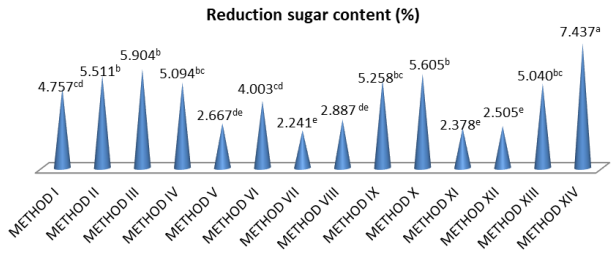

Figure 2. Average reduction sugar content of crystal coconut sugar produced from coconut sap with different tapping and shelter methods. Data labels present the mean values of treatment. Data labels with different superscript are significantly different based on DMRT α 5% test.

3.3 The sucrose content

The results of the analysis (F test) in Table 5 show that the different methods or techniques of tapping and shelter coconut sap have a significant effect on the sucrose sugar content of crystal coconut sugar products. The DMRT test results (Table 2) show that the high levels of sucrose sugar (80-90%) according to the SNI for palm sugar are found in crystal coconut sugar produced from method VII (91.51%), VIII (86.58%), V (82,42%) and VI (81.16%), and while the low sucrose sugar content (<80%) is found in crystal coconut sugar produced from coconut sap which is handled by tapping and shelter for other methods, as shown in Figure 3.

Table 5. Results of ANOVA test (F test) the effect of coconut sap tapping and shelter techniques on sucrose sugar content of crystal coconut sugar

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
Treatment	13	4701.972	1.690	8.15	<.0001 *
Block	2	5.217	2.608	1.07	0.358

*significant at α = 0.05

Method VI is tapping for 8 hrs from 06.00 AM-02.00 PM, with the addition of + 2% laru, without heating, and a shelter duration of 3 hrs. While Method VII is done in 8 hrs from 02.00 PM-10.00 PM), with 2% laru, without heating and without sheltered duration. In addition to that, method VIII was done for 8 hrs from 02.00 PM-

10.00 PM, with 2% laru, without heating and 3 hrs of shelter duration. If it is compared with SNI 3743-2021 which requires an optimum standard of sucrose content of crystal coconut sugar is 80-90%, then methods V, VI, VII and VIII of the results of this study are in accordance with the SNI quality standard. The phenomenon that occurs in the coconut sugar sucrose content is correlated with the reducing sugar level of crystal coconut sugar, which is the tapping time and duration, the combination of laru and heat and shelter duration for coconut sap determines the level of sucrose sugar in the crystal coconut sugar.

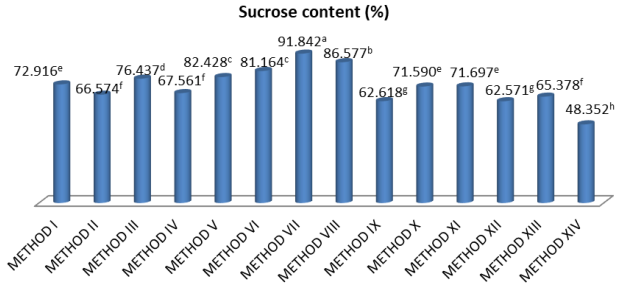

Figure 3. Average sucrose content of crystal coconut sugar produced from coconut sap with different tapping and shelter methods. Data labels present the mean values of treatment. Data labels with different superscript are significantly different based on DMRT α 5% test.

From the observations, it is known that crystal coconut sugars with high sucrose levels and low sugar reducing sugar levels are obtained from tapping sap for a maximum of 6 hrs from 06.00 AM-12.00 PM, without the addition of laru, without heating, and without shelter or processing it directly into crystals. Another method is tapping for 8 hrs from 06.00AM-02.00 PM or from 02.00 PM-10.00 PM with the addition of laru with the option of heating and a maximum length of 3 hrs for shelter.

Methods I, V, and VII are more appropriate and effective if the production process is carried out directly in the vicinity of the coconut plantation or the production house located nearby. Method VI and VIII are more appropriate and effective if the production process is not carried out directly at the coconut plantation location but in the production house which is far from the coconut plantation which requires a shelter duration of about 3 hrs.

3.4 Ash content

The results of the analysis (F test) in Table 6 show that the method of tapping and shelter of coconut sap has a significant effect on the ash content of crystal coconut sugar products. Lab test results showed that the mean ash content of the crystalline coconut sugar products from the study ranged from 1.49-2.02%. Methods IV, V, VII, and IX can produce crystal coconut sugar with lower ash content (1.49-1.89%) compared to other methods, while methods I, VI, and X produces crystal coconut sugar with relatively higher ash content (1.9-2.0%). Method IV was carried out for 8 hrs from 12.00 PM-08.00 PM, without the addition of laru, heating 95°C, shelter duration for 3 hrs. While method V was carried out for 8 hrs from 06.00 AM-02.00 PM, with 2% laru, without heating, no shelter duration. Furthermore, method VII was carried out for 8 hrs from 02.00 PM-10.00 PM, with 2% laru, without heating, no shelter duration, while method IX was carried out for 8 hrs from 06.00 AM-02.00 PM, with 2% laru, heating at 95°C, with 3 hrs of waiting time as shown in Figure 4.

Table 6. ANOVA test (F test) results the effect of tapping and shelter technique of coconut sap on the ash content of crystal coconut sugar

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
Treatment	13	0.799	0.061	1.35	0.0248*
Block	2	0.203	0.102	2.24	0.1270

*significant at α = 0.05

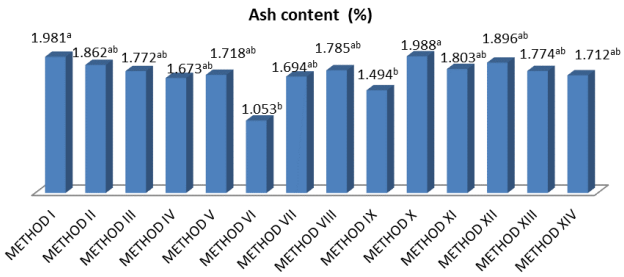

Figure 4. Average ash content of crystal coconut sugar produced from coconut sap with different tapping and shelter methods. Data labels present the mean values of treatment. Data labels with different superscript are significantly different based on DMRT α 5% test.

It was observed that the ash content of crystal coconut sugar produced from coconut sap treated with and without the addition of laru is relatively not different. This indicates that the addition of 2% laru does not significantly cause an increase in the ash content in crystal coconut sugar. The ash content of crystal coconut sugar made with 14 methods for research results in 1.49-2.02% and has met the coconut sugar ash content standard required by BSN in accordance with SNI 3743-2021, is a maximum 2.5% (National Standardization Agency, 2021).

3.5 Determination of the best (effective) coconut sap tapping and shelter method

The results of statistical analysis by the Effectiveness Index Test and taking into account the physicochemical quality indicators (reducing sugar content, sucrose content, moisture content and ash content) crystal coconut sugar was compared to the quality standard for palm sugar (SNI 3743-2021), then the order or ranking

of the best coconut sap tapping and shelter techniques were obtained, as shown in Table 7.

Table 7. Results of the effectiveness index test for determining the order of the best tapping and shelter of coconut sap methods based on the physicochemical quality of crystal coconut sugar

Rank	Total Productivity Score (Effectiveness Index)	Method
1	**0.689**	**Method VII**
2	**0.609**	**Method V**
3	**0.594**	**Method VIII**
4	**0.552**	**Method VI**
5	**0.529**	**Method I**
6	0.479	Method IX
7	0.477	Method XI
8	0.416	Method XII
9	0.406	Method III
10	0.309	Method XIII
11	0.294	Method IV
12	0.287	Method X
13	0.229	Method II
14	0.169	Method XIV

The numbers in bold indicate the best method that can produce crystal coconut sugar products with quality according to SNI 3743-2021.

Based on Table 7 it is known that 5 of the 14 methods of tapping and shelter coconut sap that can produce crystal coconut sugar quality according to SNI 3743-2021 are as followed:

(1) Rank 1 is method VII: The resulting sugar product has a sucrose content of 91.508%, reducing sugar content of 2.241%, ash content of 1.694%, and moisture content of 2.923%.

(2) Rank 2 is method V: The resulting crystal coconut sugar product has a sucrose content of 82.428%, reducing sugar content of 2.667%, ash content of 1.718%, and moisture content of 3.145%.

(3) Rank 3 is method VIII: The resulting crystal coconut sugar product has a sucrose content of 86.577%, reducing sugar content of 2.887%, ash content of 1.785%, and moisture content of 3.188%.

(4) Rank 4 is method VI: The resulting crystal coconut sugar product has a sucrose content of 81.164%, reducing sugar content of 2.503%, ash content of 1.853%, and moisture content of 3.572%.

(5) Rank 5 is method I: The resulting crystal coconut sugar product has a sucrose content of 72.916%, reducing sugar content of 4.757%, ash content of 1.981%, and moisture content of 3.216%.

4. Conclusion

Based on the results of observations and discussion, it can be concluded that the 5 best methods/techniques for tapping and shelter of coconut sap that could produce crystal coconut sugar products with quality levels of sucrose, reducing sugar, moisture and ash content according to SNI 3743-2021 for palm sugar, respectively are methods VII, V, VIII, VI and I.

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References

AOAC. (2005). Official Methods of Analysis of The Association of Analytical Chemists. Virginia USA: Association of Official Analytical Chemist, Inc.

De Garmo E.G., Sullivan W.G. and Cerook J.R. (1984). Engineering Economy. 7th ed. New York, USA: Macmillan Publication Co.

Gomez, K.A. (1995). Statistical Procedures for Agricultural Research. 2nd ed. Jakarta, Indonesia: UI Press.

Haryanti, P., Supriyadi, Marseno, D.W. and Santoso U. (2017). Chemical properties of coconut sap obtained at different tapping time and addition of preservatives. *The International Journal of Science and Technology,* 5(3), 52-59.

Karseno, Erminawati, TriYanto, Setyowati, R. and Haryanti, P. (2018). Effect of pH and temperature on browning intensity of coconut sugar and its antioxidant activity. *Food Research,* 2(1), 32-38. https://doi.org/10.26656/fr.2017.2(1).175

Mustaufik, Sutiarso, L., Rahayoe, S. and Widodo K.H. (2020). The effect of time and duration of tapping and the addition of laru as natural preservative in coconut sap quality. *IOP Conference Series: Earth and Environmental Science*, 653, 012084 https://doi.org/10.1088/1755-1315/653/1/012084

National Standardization Agency. (2021). Palm Sugar Product Quality Requirements. SNI 01-3743-2021. Indonesia: National Standardization Agency for Indonesia.

Naufalin R., TriYanto and Abdulloh, G.B. (2012). Addition of $Ca(OH)_2$ concentration and natural preservatives to improve the quality of coconut nira. *Journal of Rural Development*, 12(2), 86-96.

Sudarmadji, S., Haryono, B. and Suhardi. (1997). Analytical Procedures for Food and Agricultural Materials. Yogyakarta, Indonesia: Liberty Publishers.

