Optimizing of the Parameters of Coconut Sugar Production Using Taguchi Design in Riau, Indonesia

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***Abstract*— The quality of coconut sugar produced from Indragiri Hilir Regency, Riau Province, is still fluctuating and has not compliant with SNI-01-3743 of 1995, which incorrect parameters in its production may cause incorrect parameters in its production. Optimizing of production parameters is needed to maintain the quality of coconut sugar. Coconut sugar quality indicators can be determined from the physical-chemical and organoleptic characteristics. Therefore, it is necessary to modify the parameters of coconut sugar production, aiming to obtain optimal production parameters to produce a standard production process and coconut sugar following consumer needs and SNI. The experimental design uses the Taguchi method, which consists of 4- factor variables: (1) the type of sap preservative, (2) defoaming agent, (3) the time of tapping, and (4) the cooking temperature of the sap. The multi-response loss function approach was used to select the best production process parameters based on the typical characteristics of qualities. The results showed that the optimal production parameters were obtained in a combination of mangosteen peel and lime as sap preservative, coconut milk as a defoaming agent, long-time tapping time of 8 hours (heating) +16 hours, and cooking temperature of 135°C with a yield of 15.58%, part of water-insoluble in 0.07%, (ΔE) color 62.30, hardness 99.92 N, moisture content 6.87%, ash content 1.96%, sucrose content 77.77%, reducing sugar content 8.09% with organoleptic test values close to 4 (like) and equal SNI.**

***Keywords*— Coconut sugar; quality; Taguchi design; Indragiri Hilir.**

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I. INTRODUCTION

The development priority of Indragiri Hilir Regency places coconut as a superior regional commodity. Planted area of estate crops was 351,526 ha in 2019 [1]. Its processed products include coconut sugar, virgin coconut oil (VCO), copra, coconut oil, handicraft, activated charcoal, soap, syrup, coconut jam, and coconut flour. Of these processed products, coconut sugar is cultivated mainly by local farmers [2], [3].

Coconut sugar agroindustry prospect to be developed because of factors as follows:

- The coconut sugar business has an excellent opportunity to improve the regional economy[4], [5].
- Coconut sugar is a multi-functional product that is a direct final product for consumption and is widely used as a raw material for other products[6], [7].
- It has a long storage time without reducing its quality to be distributed to various regions.
- Coconut sugar can be produced continuously by processors or artisans throughout the year.
- The texture and taste of coconut sugar are similar to brown sugar in replacing regular table sugar[8].
- Coconut sugar can be used to alternate conventional refined sugar [9].

The quality of coconut sugar products produced in Indragiri Hilir District, Riau Province, is low on physical, chemical, and organoleptic characteristics. The color of coconut sugar still is at variance, from light brown to dark brown. The chemical quality characteristics of coconut sugar currently contain water content, ash content, sucrose content, and reducing sugar: 7.63%, 3.49%, 62.64%, and 14.92%, respectively. These values are not suitable for the Indonesian National Standard (SNI 01-3743-1995) [10] concerning the quality requirements of coconut sugar except for the quality of water content. While the organoleptic test results on a scale of 1-5, on coconut sugar from Indragiri Hilir Regency, the results of the assessment of color (3.36), aroma (3.19), taste (3.23), texture (3.20), hardness (3.25) and overall assessment (3.28). The resulting coconut sugar is a bit bitter or spicy in terms of taste. Based on this, coconut sugar tends to be disliked by consumers of brown sugar, especially in Riau Province, so it is less able to compete with brown sugar products made from palm sugar and sugar cane.

Research on the quality of coconut sugar has been done in many previous studies. Naufalin et al. [11] treated coconut palm preservatives using mangosteen peel with a concentration of 4.5%, resulting in coconut sugar with quality suitable to the Indonesian National Standard (SNI) with water content, ash content, reducing sugar content, and total sugar content of 7.50%, 2.0%, 7.30%, and 83.94%, respectively. Halolo and Susanto [12] also treated the raw material with the addition of 22% lime and 400 ppm STPP in sap to produce coconut sugar with water content (4.42%), ash content (3.46%), reducing sugar (4.22%) and total sugar (79.62%).

These studies only use 1 or 2 production parameters that affect the quality of coconut sugar produced. This study improves the quality of coconut sugar by optimizing the production process, which involves several parameters to obtain the best formulation;[13], [14], [15]. The parameters used include the composition of preservative sap, defoaming agent, tapping time, and final cooking temperature.

Adding preservatives to the sap needs to be done to maintain the quality of the sap [16]. Preservatives in sap consist of natural and chemical preservatives [17]. Natural preservatives function as anti-microbial agents that can inhibit the fermentation process of sap [18]. Producers often use natural preservatives are mangosteen peel, mangosteen sap, jackfruit wood, cinnamon, and guava leaf [11]. In contrast, sugar producers in Indragiri Hilir District use *resak* wood powder as a natural preservative for sap. The addition of chemical preservatives (sodium metabisulfite and lime) aims to maintain the pH of sap and prevent Maillard reactions[12]. Adding defoaming agent is also essential, aiming to reduce the foam due to the cooking process [19]. Defoaming agent ingredients that are often added include grated coconut, cooking oil, and coconut milk. Another factor that affects the quality of coconut sugar is the tapping time closely related to the pH of the sap produced and the final cooking temperature of the sap, which is related to the water content of the resulting sugar. This research aims to obtain optimal production process parameters to produce quality coconut sugar suitable with SNI.

II. MATERIALS AND METHODS

A. Materials and Types of Equipment

The primary material in this research was coconut sap obtained from Indragiri Hilir Regency, Riau Province. Additional materials used consist of preservatives for sap: *resak* wood powder, mangosteen peel, sodium metabisulfite, lime solution, defoaming agent, grated coconut, cooking oil, and coconut milk. Materials for analysis using; distilled water, Pb Acetate, Nelson reagent, 30% HCl, 45% NaOH.

Types of equipment used for tapping and cooking sap were jerry cans, filter cloth, scale, plastic measuring cup, frying pan, stove, stirring spoon, thermometer, sugar mold. While the tools for analysis are pH meter, hand refractometer, oven (Sanyo MOV-112, Japan), muffle furnace (Thermolyne 1400), test tube, pipette, Erlenmeyer (pyrex).

B. Procedure

The preservative for the sap is weighted according to the estimated amount of sap obtained. This preservative is then put into a jerry can for the sap and attached to the tapped coconut. 1 liter of preservative sap added is 0.1% (w/v) mangosteen peel, 0.07% (w/v) *resak* wood powder, 0.15% (w/v) sodium metabisulfite and 2% (v/v)) lime solution (adjusted to treatment). The duration of the tapping consists of; (1) morning tapping (8 hours), (2) morning tapping (8 hours) + afternoon tapping (16 hours), and (3)24-hour tapping. The tapped sap is filtered to remove the impurities and then cooking the sap with the final cooking temperature ranging from 130-140 °C for 90-100 minutes. To eliminate the foam during the cooking process, add defoaming agent ingredients grated coconut 0.1% (w/v), cooking oil 0.1% (v/v) and coconut milk 0.1% (v/v) (selected according to treatment). After the sap coagulates, it is followed by a cooling process while stirring it, and the molding process is done.

C. Research Design

Based on previous research, literature, and field observations, 4 (four) factors and levels were selected as production parameters:

TABLE I
FACTORS AND TREATMENT LEVELS

No	Factor	Level 1	Level 2	Level 3
1	Composition of preservative sap (A)	ARNa.1	AMNa.2	AMCa.3
2	Defoaming agent (B)	BK1	BM2	BS3
3	Tapping time (C)	CW1	CW2	CW3
4	Final cooking temperature (D)	DT1	DT2	DT3

TABLE II
DESIGN OF ORTHOGONAL ARRAY EXPERIMENTS

Experiment	Factor			
	A	B	C	D
1	ARNa.1	BK1	CW1	DT1
2	ARNa.1	BM2	CW2	DT2
3	ARNa.1	BS3	CW3	DT3
4	AMNa.2	BK1	CW2	DT3
5	AMNa.2	BM2	CW3	DT1
6	AMNa.2	BS3	CW1	DT2
7	AMCa.3	BK1	CW3	DT2
8	AMCa.3	BM2	CW1	DT3
9	AMCa.3	BS3	CW2	DT1

Information:
ARNa.1 = Preservative factor, *Resak* wood powder 0.07% (w/v) and $Na_2S_2O_5$ 0.15% (w/v)
AMNa.2 = Preservative factor, mangosteen peel 0.1% (w/v) and $Na_2S_2O_5$ 0.15% (w/v)
AMCa.3 = Preservative factor, mangosteen peel 0.1% (w/v) and $Ca(OH)_2$ 2% (v/v)
BK1 = Defoaming agent factor, grated coconut 0.1% (w/v)
BM2 = Defoaming agent factor, cooking oil 0.1% (v / v)
BS3 = Defoaming agent factor, coconut milk 0.1% (v/v)
CW1 = Tapping time factor, 8 hours
CW2 = Tapping time factor, 8 hours (heating) + 16 hours

CW3 = Tapping time factor, 24 hours
DT1 = The final temperature factor, 130°C
DT2 = The final temperature factor, 135°C
DT3 = The final temperature factor, 140°C

D. Testing the parameters of Coconut Sugar Qualities

In this study, coconut sugar was tested for physical quality characteristics, including yield, water-insoluble parts, color, and hardness. Chemical quality characteristics include moisture content using the oven method and ash content using the dry ashing method, sucrose sugar content, and reducing sugar content using the Nelson-Somogyi. In addition, the organoleptic test includes color, taste, aroma, texture, hardness, and overall assessment.

E. Data processing

According to Madan and Wasewar [20], the steps of calculating data through the Taguchi method begin with calculating the average value, S/N ratio, analysis of variance (ANOVA), and the multi-response loss function calculation. The quality characteristics of coconut sugar are determined and identified based on quality from the appropriate S / N ratio. The characteristics of the quality value of the S / N ratio calculation that are intended are 1) Larger the better (LTB), which is the more excellent value will be the better quality (equation 1), 2) Nominal the best (NTB), which is intended at a specific value (equation 2), 3) Smaller the better (STB), which is the smaller value will be the better quality (equation 3). ANOVA was used to determine the factors that contributed to the experiment results. The multi-function response calculation to determine the optimal treatment combination is based on the tested quality characteristics.

$$\eta = -10\ log\left(\frac{1}{n}\sum_{i=1}^{r} y_i^2\right) \quad (1)$$

$$\eta = 10\ log_{10}\left[\frac{\mu^2}{\sigma^2}\right] \quad (2)$$

$$\mu = \frac{1}{n}\sum_{i=1}^{n} y_i^2$$

$$\sigma^2 = \frac{1}{n-1}\sum_{i=1}^{n}(y_i - \mu)^2$$

$$\eta = -10\ log\left(\frac{1}{n}\sum_{i=1}^{r}\frac{1}{y_i^2}\right) \quad (3)$$

η is the ratio S / N, n is the number of repetitions in each experiment, and yi is the value in each experiment repeated to- i.

The next step is the calculation of the multi-response to noise. Calculations to make recommendations for optimal factor levels in coconut sugar production use multi-response calculations based on the loss function Taguchi method approach using equation (3). The results obtained were transformed into a ratio to noise (SNR) using equation (4) and made a factor effect table.

$$TL_j = \sum_{i=1}^{r} w_i\, x N_{ij} \quad (4)$$

$$\eta = -10log(TL_j) \quad (5)$$

TLj is the total loss function, wi is the number of response variables, and ηj is the SNR value.

This study was conducted with a confirmatory experiment to validate the conclusions obtained during the analysis [20] and test the combination of factors and levels. The results of confirmatory trials should be within the optimal confidence interval (5). The confidence interval for the confirmation experiment is calculated based on equation (6).

$$Cl_{mean} = \pm\sqrt{F_{\propto;v1;v2} x MS_e x \frac{1}{neff}} \quad (6)$$

$$Cl_{mean} = \pm\sqrt{F_{\propto;v1;v2} x MS_e x\left(\frac{1}{neff} + \frac{1}{r}\right)} \quad (7)$$

Fα; v1: v2 is the F-ratio value of the table, α is the confidence level, v1 is the degrees of freedom for the numerator, which corresponds to the mean, and the value is always equal to 1 for the confidence interval. v2 is the degrees of freedom for the denominator according to the degrees of freedom from variation errors collected. MSe is the variation of errors collected, neff is the number of practical observations, and r is the number of replications.

III. Results and Discussion

The quality of coconut sugar is influenced by the quality of sap, the primary raw material for making coconut sugar. The indicator for sap quality can be determined by the pH value and the Brix value of the sap. The pH value of sap from all experiments ranged from 6.08 to 6.99. This value has suitable for the optimal pH value for the production of molded brown sugar. It is consistent with the assumption by Suwardjono [21] that the optimal pH value of sap to be used, like brown sugar, is in the range of 6.0 - 6.5.

In comparison, Brix is the content of solids that dissolves for every 100 grams of solution, which is the amount of solid sugar and other solids, not sugar, so the estimated sugar content in the sap can be considered as the Brix value [22]. According to[18], the sugar content in coconut sap ranges from 13-14% [23] and 12.40 ± 1.14 [8]. The experimental Brix value is already in the range of values from 14.62 to 16.02. The average value and SNR calculation were carried out on coconut sugar's physical, chemical, and organoleptic parameters, as shown in Tables 3, 4, and 5. The details of the results are presented in the following subsections.

A. The yield

The characteristics of the yield qualities in the study were LTB. The greater the yield value is, the better. The highest yield value was found in experiment 2, while the low sugar yield was found in experiments 3, 5, and 7 with a tapping time (CW3) of 24 hours, which resulted in a low pH of sap resulting in increasing by reduction sugars in the form of glucose and fructose which had high solubility. So that it cannot crystallize, resulting in a low yield of sugar, and sugar becomes easily damaged [12].

The ANOVA calculation results show that the production process factors that affect the yield of coconut sugar are the tapping time factor (C) and the cooking temperature factor (D). The influence of factor C is 45.34%, and factor (D) is 9.75%.

B. The insoluble parts in water

The characteristics of the quality of parts that are not soluble in water are Small The Better (STB), where the smaller the number of parts that are not soluble in water, the better the quality of coconut sugar produced. The experimental mean values ranged from 0.06-0.21%. This value is relatively small compared to the value required in SNI to a maximum of 1%. The average SNR values ranged from 13.51 to 23.90%. The insoluble solid content is identical to the impurities or other materials added during the printing sugar process [24]. The ANOVA calculation shows that the factor of the production process that affects the parts that are not soluble in coconut sugar water is only the anti-foam factor (B), with a practical contribution of 75.56%.

TABLE III
THE AVERAGE VALUE AND SNR OF PHYSICAL CHARACTERISTICS OF COCONUT SUGAR

No	Experiment	The yield		The insoluble parts in water		Color		Hardness	
		Average	SNR	Average	SNR	Average	SNR	Average	SNR
1	I	16.50	24.32	0.17	15.29	47.69	33.46	24.62	30.66
2	II	16.77	24.44	0.07	22.28	56.57	35.02	64.95	31.85
3	III	14.03	22.89	0.09	21.24	62.69	35.94	121.50	21.21
4	IV	16.17	24.17	0.21	13.51	65.03	36.26	41.93	18.07
5	V	14.77	23.38	0.09	21.10	55.18	34.82	2.70	2.82
6	VI	16.00	24.05	0.10	20.31	61.77	35.81	54.95	22.75
7	VII	14.97	23.50	0.19	14.04	62.65	35.93	81.67	37.03
8	VIII	14.93	23.48	0.08	21.39	64.88	36.24	47.45	21.20
9	IX	16.30	24.24	0.06	23.90	52.65	34.37	51.30	14.42

TABLE IV
THE AVERAGE VALUE AND SNR CHEMICAL CHARACTERISTICS OF COCONUT SUGAR

No	Experiment	Water content		Ash content		Sucrose levels		Reducing Sugar Levels	
		Average	SNR	Average	SNR	Average	SNR	Average	SNR
1	I	7.32	-17.30	2.13	-6.59	82.15	38.28	2.77	-8.85
2	II	7.02	-16.97	1.91	-5.66	82.57	38.33	2.87	-9.39
3	III	5.31	-14.53	2.14	-6.62	76.08	37.62	11.41	-21.15
4	IV	6.56	-16.51	2.13	-6.57	80.95	38.16	5.55	-14.91
5	V	8.25	-18.35	1.96	-5.86	67.23	36.48	20.11	-26.27
6	VI	7.21	-17.18	1.99	-5.96	79.24	37.98	6.07	-15.67
7	VII	7.27	-17.24	2.15	-6.68	80.73	38.13	5.35	-14.58
8	VIII	6.60	-16.41	1.93	-5.70	73.81	37.36	5.37	-14.60
9	IX	7.58	-17.60	1.70	-4.64	74.74	37.46	3.14	-10.31

TABLE V
THE AVERAGE VALUE AND SNR ORGANOLEPTIC CHARACTERISTICS OF COCONUT SUGAR

No	Experiment	Color		Flavor		Taste		Texture Test		Hardness Test		Overall assessment	
		Average	SNR	Average	SNR	Average	SNR	Average	SNR	Average	SNR	Average	SNR
1	I	2.68	8.53	2.80	8.95	3.55	11.01	3.65	11.24	3.57	11.06	3.54	10.97
2	II	3.66	11.27	3.60	11.12	3.59	11.09	3.61	11.13	3.54	10.95	4.13	12.32
3	III	3.81	11.62	3.61	11.14	3.67	11.28	3.47	10.81	3.61	11.14	3.74	11.46
4	IV	3.90	11.83	3.52	10.92	3.27	10.28	3.69	11.33	3.57	11.05	3.72	11.41
5	V	2.96	9.41	3.36	10.52	3.70	11.36	3.20	10.04	3.01	9.56	3.54	10.96
6	VI	3.72	11.42	3.46	10.79	3.97	11.98	3.72	11.41	3.71	11.38	3.75	11.48
7	VII	4.09	12.23	3.64	11.23	3.93	11.87	3.79	11.55	3.61	11.14	3.81	11.62
8	VIII	3.69	11.33	3.29	10.35	2.96	9.41	3.68	11.31	3.63	11.21	3.88	11.76
9	IX	2.96	9.35	3.14	9.94	3.58	11.07	3.55	11.01	3.53	10.95	3.78	11.53

C. Color

LTB chose the physical color characteristics of coconut sugar. The more it leads to dark brown, the better the color of coconut sugar. The tendency to experiment with a lower cooking temperature (130ºC) makes the ΔE value lower. On the other hand, a high cooking temperature (140ºC) will result in a higher ΔE value. The brown color of coconut sugar is also caused by a browning reaction or a Maillard reaction during the sugar cooking process. The Maillard reaction is a non-enzymatic browning reaction that occurs through reactions between carbonyl groups of reducing sugars, especially with primary amino groups of amino acids, peptides, and proteins [18], [25], [26]. The Maillard reaction does not require a high temperature, but the reaction rate will increase sharply at high temperatures and cause browning to occur more rapidly. Karseno et al. [6] reported that the increasing temperature during heating coconut palm could increase the browning reaction so that the browning intensity value is also high.

The ANOVA calculation results also show that the production process factors that affect the color of coconut sugar are the cooking temperature (D) and the sap preservative composition factor (A). The contribution of influence from factor D is 69.29%, and factor (A) is 14.79%

D. Hardness

The characteristics of the hardness quality of sugar produced in this study were NTB based on consumers' organoleptic hardness test. The hardness value favored by consumers is in experiment 7, with a hardness value of 81.67 N. The lowest hardness value is in experiment 5. Low cooking temperature (DT1) makes the water content of the resulting coconut sugar high. The lower the cooking temperature, the less water is evaporated so that the water content will be higher—high water content results in softer sugars [27]. The results of the ANOVA calculation of the factors that influence hardness are found in all factors in the production process with the contribution of the influence of the D factor of 38.79% (A) 23.52%, factor (B) 23.77%, and factor (C) 11.07%.

E. Moisture content

The characteristic of water content quality in this research was smaller, the better. The brown sugar SNI requires a product moisture content <10%. The average moisture content of coconut sugar ranged from 5.31 to 8.25%, with the highest moisture content found in experiment 5 and the lowest found in experiment 3. Even though the tapping time was the same between experiments 3 and 5, it resulted in a different pH value of sap; in experiment 5, the pH of the sap is lower than that of experiment 3. The low pH value of sap causes the reduction of sugar to be higher because, in acidic conditions (low pH of sap), there is the hydrolysis of sucrose to glucose and fructose, which are a group of reducing sugar. The water content will be higher with the higher the reducing sugar content, especially fructose. Fructose is hygroscopic, so it quickly absorbs water or moisture in the environment. High humidity in the environment can cause brown sugar to quickly absorb water vapor resulting in an increase in water content and a decrease in the texture of brown sugar [28].

F. Ash content

The characteristics of the quality of the ash content in this study were smaller the better. SNI for molded brown sugar requires that the ash content of sugar products is <2%. The ash content in the material is influenced by the mineral content in it and the manufacturing process [29]. According to Subagio [30], the ash content of coconut meat ranges from 2.92-4.33%, which is a mineral source; this gives a significant contribution to the ash content of coconut sugar which is added with grated coconut. Meanwhile, the ash content of cooking oil and coconut milk is more diminutive than grated coconut, with a value of 0.55% [31] for coconut milk and 0.053% for cooking oil [32]. ANOVA calculation results show that only factor B affects the ash content of coconut sugar with a contribution of 20.69%.

G. Sucrose levels

The characteristics of the quality parameters of the sucrose content in this study were Large the better. Based on the SNI for brown sugar, the required minimum sucrose content is ≥ 77%. The average response to sucrose levels ranged from 67.23 to 82.57%. Experiments 3, 5, 8, 9 have sucrose levels that do not suit the SNI requirements for brown sugar. The lowest value of sucrose content was experiment 5. The low level of sucrose in experiment 5 was because the Brix value of sap in experiment 5 also had a low value. The results of ANOVA calculation, all process parameter factors affect the value of sucrose with the contribution of each of these factors to the value of sucrose levels, namely factor (A) 12.02%, factor (B) 26.55%, factor (C) 12.96% and factor (D) 21.22%. The BM2 treatment resulted in coconut sugar with the lowest levels of sucrose. The addition of oil as defoaming agent indirectly affects the sucrose content of the coconut sugar produced. According to Dwiyanti et al. [33], the use of oil as defoaming agent in the coconut sugar processing process will cause an increase in the amount of fat which will hinder the crystallization process of sucrose, which prevents the interaction between sucrose molecules because fat acts as an impurity so that the resulting sugar becomes soft or mushy. Soft sugar indicates that the sugar contains many reducing sugars that are hygroscopic, one of which is due to the hydrolysis of sucrose in the sap raw material and the hydrolysis of sucrose during the coconut sugar production process.

In addition to factor B, which affects sucrose, is the factor (D) temperature at the end of cooking. The cooking process will inhibit the fermentation of the sap so that it can maintain the sucrose levels in the sap. Srikaeo et al. [34] reported that high temperatures in the sap could activate the invertase enzyme. The optimal activity of the invertase enzyme is in the temperature range of 25-60ºC [35] so that the invertase reaction in sucrose to reducing sugar can be reduced or inhibited. This condition can cause sucrose levels to experience less reduction during the process—the final cooking temperature, which results in a high sucrose value at DT2.

H. Reducing Sugar Levels

Sucrose and reducing sugar have a relationship where the higher the reducing sugar content, the lower the sucrose content. This fact is because the hydrolysis of sucrose produces the reducing sugar in the sugar by the invertase enzyme released by yeast contaminated with sap [18]. Improper handling of sap will increase the amount of reducing sugar, resulting in low levels of sucrose sugar in the resulting sugar. The ANOVA calculation results show that all factors of production parameters affect the content of this coconut sugar reduction level. The contribution of each factor, namely, factor (A) 21.49%, factor (B) 12.41%, factor (C) 46.74% and factor (D) 7.99%. The tapping time has the most effect on reducing sugar. CW3 is a treatment with a high average reducing sugar content. This fact is because the pH of the sap produced from the treatment is low. The low pH value of sap causes the reducing sugar to be higher because the sap in low pH conditions causes the hydrolysis of sucrose to glucose and fructose, reducing sugar groups[6]. The choice of preservative for the sap makes a big contribution to maintaining the pH of the sap. AMCa.1 treatment is a preservative for sap that can produce a high pH value sap.

I. Color Organoleptic Test

The color most preferred by respondents is experiment 7, where the sugar produced is dark brown. Meanwhile, consumers do not like the color of coconut sugar in experiments 1, 5, and 9, wherein the color of the sugar produced is pale brown-light brown. The three experiments have in common the low cooking temperature at 130ºC. The results of ANOVA calculations show that 3 of the four factors of the production process affect the organoleptic test of the color of coconut sugar, namely the cooking temperature factor (D), the tapping time factor (C), and the preservative composition factor (A). The influence contributions of each factor D, C, and A were 87.32, 4.41, and 2.55%.

J. Flavor Organoleptic Test

The flavor of coconut sugar that consumers want is the distinctive flavor of coconut sugar, one of coconut sugar's superiority[6]. The arising of food aromas is caused by volatile compounds (volatile) in the material [18]. The higher temperature will stimulate the flavor of cooking sugar. The ANOVA calculation results show that all production process factors affect the organoleptic test of coconut sugar flavor, namely final cooking temperature (D) with a contribution of 59.77%, then the tapping time factor (C) with a practical contribution 30.66%. Whereas for the preservative (A) composition and the defoaming agent (B), the effect's contribution tends to be minor, with a value of 2.98% and 2.33%.

K. Taste Organoleptic Test

Based on table 5, the taste most preferred by the panelists was in experiment 6, while the taste was most disliked in experiment 8. The DT3 factor, namely the final cooking temperature of 140°C, was thought to be the leading cause of experiment 8 being less preferred by consumers because the sugar produced was bitter. The ANOVA calculation results show that all production process factors affect the organoleptic test of coconut sugar taste. The most influential factor is the final cooking temperature (D), with a contribution of 49.22%. Meanwhile, the defoaming agent factor (B) and the time tapping factor (C) had a relatively significant influence, 17.79%, and 17.29%. The preservative composition factor (A) has a negligible effect with a value of 3.65%.

L. Organoleptic Texture Test

The average assessment of coconut sugar texture ranged from 3.20 to 3.79. Experiment 7 is the most preferred texture by panelists because of its more compact texture. The ANOVA calculation shows that the production process factor that affects the organoleptic test of coconut sugar texture is the final cooking temperature factor (D), with a contribution of 22.71%. Defoaming agent factor (B) with a contribution of 17.68% and tapping time factor (C) with a contribution of 15.33% influence.

M. Organoleptic Hardness Test

Panelists' ratings of sugar hardness ranged from 3.01 to 3.61. The lowest hardness value in experiment 5 is because the resulting sugar is relatively soft. Low cooking temperature is thought to be the leading cause of soft coconut sugar because there is still a lot of water content in coconut sugar. The ANOVA calculation results show all factors of the production process that affect the organoleptic test of coconut sugar hardness. The contribution of the effect of each factor is the final cooking temperature factor (D) with a contribution of 29.58%, the defoaming agent factor (B) with a contribution of 21.36%, and the tapping time factor (C) with a contribution of 15.33% influence and a factor of preservative composition with a contribution of 11.02%.

N. Overall assessment organoleptic test

Based on the panelists' assessment of overall assessment, the authors liked the appearance of all product experiments with an average score of 3.54-4.13. The highest experimental organoleptic test value was in experiment 2, and the lowest was in experiment 5. The ANOVA calculation results showed all factors of the production process that affect the organoleptic test of the appearance of coconut sugar. The contribution of the influence of each factor was the final cooking temperature factor (D) with a contribution of 43.07%, the tapping time factor (C) with the influence of 33.98%, the defoaming agent factor (B) with a contribution of 4.92% and the preservative composition factor with a contribution of 3.66%.

O. Multi Response Analysis with Taguchi Loss Function Approach

In this study, more than one observed response parameter for the quality characteristics of coconut sugar included 14 quality parameters, so a multi-response analysis was necessary. This analysis begins by calculating the loss function for each quality parameter and normalizing the data on each characteristic value for each parameter need to be done to equalize these characteristics. The calculation was continued by calculating the total loss function as a combination of all quality parameters. The multi-loss function calculation results are transformed into the calculation of the effect of the SNR factor to analyze the factors and levels. Therefore, the optimal modification process was obtained in the coconut sugar production: the combination of final cooking temperature 135°C, tapping time 8 hours of heating + 16 hours of tapping in the afternoon, and preservatives. The sap was used in combination with mangosteen peel and lime and coconut milk as a defoaming agent (Fig.1).

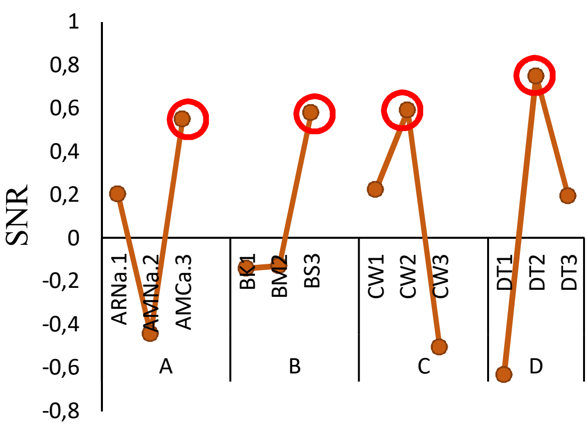

Fig. 1 Factor Effect SNR Multi Respon

P. Confirmation Experiments

This experiment was carried out based on the factors and optimal condition levels obtained from calculating the multi-response loss function of 5 samples. The confirmation test results mean the confirmation experiment's quality value is in the optimal condition interval. This finding indicates that the optimal factor level combination produced in this study can improve the quality of coconut sugar. The processed data obtained that improving coconut sugar production parameters in Indragiri district could improve the physical-chemical and organoleptic quality, all confirmation experiments suitable the SNI requirements from brown sugar.

IV. CONCLUSIONS

Optimization of the coconut sugar production process in Indragiri Hilir Regency, Riau Province was obtained in a combination of final cooking temperature treatment of 135°C (DT2), tapping time of 8 hours (heating) + 16 hours (WS2), types of mangosteen peel preservative and lime (AMCa. 3), defoaming agent coconut milk (BS3). The results showed a yield of 15.58%, parts that are not soluble in water 0.07%, (ΔE) color 62.30, hardness 99.92 N, water content 6.87%, ash content 1.96%, sucrose content 77.77%, reducing sugar content 8.09 % with the average value of the organoleptic test is 3.85 (likes) and suitable SNI 01-3743- 1995.

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