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Making *Eucheuma cottonii* Doty Jam with Various Palm Sugar Concentrations

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Abstract. Seaweed is a biological resource abundantly available in Indonesia, yet it has been hardly used or consumed. This study aimed to analyze the influence of palm sugar [*Arenga pinnata* (Wumb) Merr.] concentration on the quality of *Eucheuma cottonii Doty* seaweed jam using true experimental research design. The concentrations of palm sugar were 0%, 30%, 40%, 50%, 60%, and 70%. The results showed that there was an effect of palm sugar concentration on the quality of *Eucheuma cottonii Doty* seaweed jam. The best treatment in this study was palm sugar concentration of 70%. In this treatment, water content, total sugar, and total soluble solids of seaweed jam were 33.60%, 64.89%, and 54.15%, respectively. In general, the addition of palm sugar improves seaweed jam quality.

Keywords: *Eucheuma cottonii Doty,* jam quality, palm sugar

1. Introduction

Seaweed is one of the most favored and developed marine products in all Indonesian waters and has population up to 384.73 thousand ha [1,2]. In 2010, Indonesia produced the highest amount of seaweed, harvesting 5.632 tons of wet seaweed [3]. The export of Indonesian seaweed continued to increase during the period of 2010-2014 with 14.04% export value and 11.7% export volume per annum [4]. Then, in 2016, Indonesia exported 183.257 tonnes of seaweed and earned USD 133 million from that sector [5]. So far, Indonesia and China have become the two largest seaweed producer countries [5,6]. The presence of those large quantities of seaweed originates from original stock as well as from seaweed cultivation carried out by Indonesian people [2,7–9].

Although Indonesia is positioned as the largest seaweed producer, Indonesia is not among the largest seaweed consuming countries. [5,10]. This condition is related to the unfamiliarity of the Indonesian people in consuming seaweed compared to other countries [11]. The consumption of seaweed in Indonesia is relatively low. Out of 100% total national seaweed production, 64% was exported in the form of dried seaweed while the remaining 36% was used in the domestic industry [12]. The typical aroma of seaweed seems to be the cause of the low consumption of seaweed, whether it is fresh or processed [13]. Besides, despite a large amount of seaweed in the Indonesian archipelago, sufficient effort has not been made to increase its potential.

Eucheuma cottonii Doty is a seaweed species in red algae class, which is widely cultivated in Indonesian waters [14]. *E. cottonii* is also the most dominant algae exported by Indonesia [5]. *E. cottonii* contains various essenstial nutrients and is useful in maintaining human's health. Some bioactive compounds are also contained in these algae, such as flavonoids, hydroquinone phenols, and triterpenoids [15]. In addition, *E. cottonii* also has the potential to be a natural source of anti-tyrosinase [16]. *E. cottonii* extract also shows antioxidant activity and provides a protective effect against UV, so it is indicated to be able to be useful as a nutrient for skin rejuvenation [17]. Moreover, based on several studies, *E. cottonii* has the potential as a natural candidate for anti-cancer drugs, such as cervical cancer [18] and breast cancer [19,20].

The use of seaweed can be maximized through the diversification of seaweed products. One of the diversifications is by using *E. cottonii* as an ingredient for making jam. *E. cottonii* can be used as jam making ingredient since it contains carrageenan [21,22]. Carrageenan is a natural carbohydrate which belongs to the class of polysaccharides [23]. This carbohydrate is a hydrocolloid substance used as a thickening and gelling agents, substances needed in making jam [24,25].

In addition to the presence of hydrocolloid substances, certain conditions also need to be considered during producing seaweed jam. These conditions may affect the quality of jam and the attention of consumers. Some of these conditions, including texture, aroma, to the taste of jam produced [26,27]. In addition, the sweet taste of jam also affects the level of consumer preferences in consuming jam. The use of type and concentration of sugar will determine the sweetness and characteristics of the jam produced [28–30]. In general, sugar tables are a type of sugar used as ingredients for making jam. In fact, there are other types of sugar that have the potential as a sweetener in producing quality jam; one of them is palm sugar.

Palm sugar is a sugar commonly found in Indonesia and comes from sugar palm trees [*Arenga pinnata* (Wumb) Merr.] [31]. The tree is naturally spread in various regions in Indonesia [32–34]. Interestingly, palm sugar is also said to be healthier than table sugar [31,34]. Palm sugar is also reported to have a lower glycemic index [35]. Furthermore, besides being a natural sweetener, palm sugar also has antioxidant activities that can play a role when the body is contaminated by free radicals [36].

The utilization of *E. cottonii* as the main ingredient of jam is still rarely found. In addition, the substitution of table sugar with palm sugar in the producing jam has been seldom to be conducted. Therefore, this study will provide new information on the innovation of seaweed-based food products in Indonesia.

2. Methods

2.1. Research design

The research design used in this study was True Experimental Research to determine the differences in the concentration of palm sugar towards the quality of *E. cottonii* jam. The list of palm concentrations used in this study is presented in Table 1. The jam qualities observed in this study were from water, sugar, and total soluble solids content as well as organoleptic parameters. *E. cottonii* jam making was done at the Biology Laboratory, University of Muhammadiyah Malang (UMM), Indonesia. Water content analysis was carried out at the Animal Science and Nutrition Laboratory, UMM. Total sugar content analysis was carried out at Food Quality and Safety Testing Laboratory, Brawijaya University. The total soluble solids analysis was conducted at the Food Technology Laboratory, UMM. Finally, organoleptic tests were carried out in the Biology Laboratory, UMM.

Table1. Treatment code and palm sugar concentration

Treatment Codes*	Palm Sugar Concentration (%)
K1	0
K2	30
K3	40
K4	50
K5	60
K6	70

**code used to summarize the details of the concentration of each treatment. K = group*

2.2. Materials
The main ingredients utilized in this study were *E. cottonii.* and palm sugar (*Arenga pinnata)*. *E. cottonii* obtained from Sumenep, Madura, whereas the palm sugar used was "Nira Murni Gula Aren", one of palm sugar trade names from Indonesia. Seaweed used was confirmed to be *E. cottonii* Doty after the identification step was carried out at Central Laboratory of Islamic University of Malang

2.3. The production of E. cottonii jam
Initially, dried *E. cottonii* was cleaned from the remaining dirt. Then, the seaweed was soaked in water for three days. In each morning and afternoon, the water changed. After three days, the seaweed was dried and seaweed porridge was made by mixing 100 grams seaweed with 50 mL of water until became smooth. After that, the ingredient of seaweed jam that consisted of 200 grams seaweed, 1.5 grams' citric acid, 148.5 mL of water and palm sugar (according to each treatment in Table 1) were prepared. Those ingredients were cooked for 20 minutes at a temperature of approximately 95 ºC. Finally, the seaweed jam was put into the bottles.

2.4. Water content analysis
The water content was analyzed based on the Indonesian National Standard (SNI) 2891: 1992 point 5.1. Initially, as much as 1-2 grams of sample was weighed. Then, the sample was dried in an oven at 105 ºC for 3 hours. After that, the samples were cooled in a desiccator and repeated several times until the sample weight was constant. Furthermore, the water content was calculated by dividing the sample weight before drying with the sample weight after drying.

2.5. Total sugar content analysis
The testing of sugar content was done using Anthrone method. This method is divided into two major steps, making a standard curve and determining the sugar content contained in the sample. The steps for making a standard curve are as follows. Standard glucose solution of 0.0; 0.2; 0.4; 0.8, and 1.0 mL was inserted into the test tube. Then, distilled water was added to each tube until it reached 1 mL. Then, 5 mL of anthrone reagent was added to each tube. Each tube was covered with aluminum foil and homogenized. After that, each tube was heated in a water bath for 12 minutes at 100 ºC. Then, the cooled solution was transferred into the cuvette and the color intensity recorded in the spectrophotometer with a wavelength of 620 nm. Then, a standard curve was created. In determining the sugar concentration from the sample, 1 mL of the sample was diluted in a test tube, and the same procedure as in making a standard curve analyzed the sample

2.6. Total soluble solids content analysis
The testing of soluble solids based on SNI 3746: 2008 used refractometer. At first, the sample was weighed as much as 40 grams and then mixed with 150 mL of water. Then, the mixture was heated to boil for 2 minutes. After that, the sample was left to stand for 20 minutes then filtered and weighed. Next, two drops of sample solution were dropped into the refractometer prism. The results of the refractometer were recorded.

2.7. Organoleptic test
Organoleptic test in this study was carried out using hedonic test method. The hedonic test is an assessment based on a person's preference level on a sample that is presented based on a hedonic scale determined by thirty assessors.

2.8. Data analysis
The data from water content, total sugar content, and total soluble solids test were analyzed using one-way ANOVA followed by Duncan's Multiple Range Test (DMRT), whereas the data from the organoleptic test were analyzed using Kruskal-Wallis H test. The prerequisite tests (normality and homogeneity test) were conducted prior to ANOVA test.

3. Results and Discussion

In this study, seaweed jam made from *E. cottonii* and palm sugar with different concentrations was produced. Seaweed jam produced from each treatment is presented in Figure 1. Based on Figure 1, each treatment could produce seaweed jam. However, the color of jam from each treatment was different. Then, the results of one-way ANOVA are summarized in Table 2. and DMRT results are presented in Table 3.

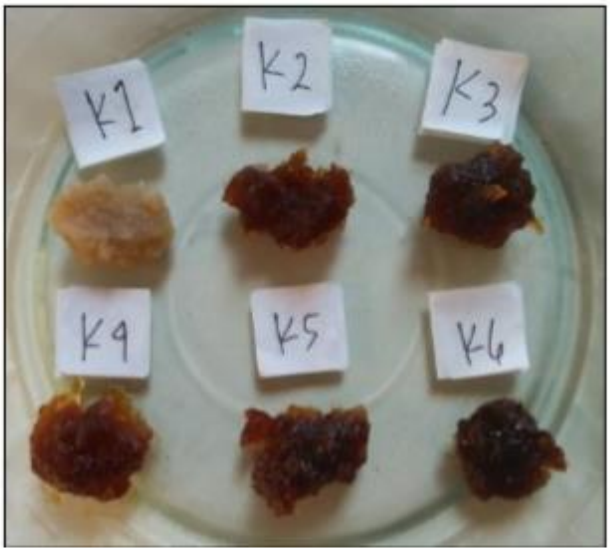

Figure 1. Seaweed jam samples produced from each treatment. The details of each treatment can be seen in Table 1

Table 2. The ANOVA Results of the effect of sugar concentration on water, sugar, and soluble solids content of jam

Sources	Df	Water Content	Sugar Content	Soluble Solids
Treatment	5	65.951*	108.768*	75.542*
Error	18			

**Significant at 5%*

Table 3. The DMRT results of water, sugar, and soluble solids content of each treatment

Treatment Codes*	Water Content	Sugar Content	Soluble Solids
K1	92.80^{e}	1.56^{a}	5.42^{a}
K2	53.79^{d}	53.99^{c}	41.58^{b}
K3	50.69^{cd}	47.37^{b}	44.66^{bc}
K4	45.14^{bc}	45.67^{b}	48.47^{cd}
K5	41.50^{b}	59.27^{cd}	51.94^{d}
K6	33.60^{a}	64.89^{d}	54.15^{d}

Note: The scores followed by the same alphabets show that there was no significant difference on $p < 0 .05$.
**The details of treatment can be seen in Table 1.*

3.1. *The water content of jam*

Water content is the amount of water in certain materials. It usually affects the appearance, texture, and taste of food hence, it becomes one of the most important aspects in food materials [37–39]. The water content in food products like jam is also significant due to affecting its quality [40]. Based on

Table 2, it can be seen that the difference in the palm sugar concentration had a significant effect on the water content level of jam [F (5.18) = 65.951), $p < 0.05$]. After that, based on Table 3, K1 (palm sugar concentration of 0%) was the treatment produced jam with the highest water concentration. On the other hand, K6 (palm sugar concentration of 70%) was the treatment that had the lowest water concentration. Besides that, the data portrayed that the more sugar concentration, the lower water concentration produced. This result is in line with some previous reports, such as Khan *et al.* that studied the effect of sugar concentration on *sapodilla* jam quality [29].

Sugar contains hygroscopic molecules that can bind water [41]. The sugar molecule has a hydroxyl group which is capable of forming intramolecular hydrogen bonds. The bond produces stable hydrate and causes water to be trapped in the gel [42,43]. Because of its ability, the increase in sugar will further reduce the amount of free water.

According to SNI, the maximum water content in the jam is 35%. The K6 treatment (palm sugar concentration of 70%) produced jam with appropriate water content in accordance with SNI. Adding palm sugar concentration of less than 70% resulted in water content of jam exceeding the standard level set by SNI. The less water content obtained, the better the quality of jam produced.

The low water content in food inhibits the growth of microorganisms, so the food is not easily damaged and can last longer [44]. The low water content in food products results in the unavailability of water for the microorganism growth. This condition makes food products become more durable and long lasting because the microorganisms in the food are inactive [45]. The presence of microorganisms is the cause of food products to be easily damaged and deteriorate in quality.

3.2. *Total Sugar Content in Eucheuma cottonii Doty seaweed jam*

Total sugar content is the sugar contained in a product, which is commonly derived from sugar (sucrose), glucose, and inverted sugar (fructose and glucose) [46]. The level of sugar concentration in food products will determine the level of sweetness of the food product [47,48].

Based on Table 2, it was found that there was an effect of various concentrations of palm sugar on the total sugar content in *E. cottonii* jam [F (5.18) = 108.768), $p < 0.05$]. Furthermore, based on Table 3, the higher of palm sugar proportion in seaweed jam formula, the higher sugar content in seaweed jam were produced. This result is in line with some previous studies, such as Gaffar *et al.* who studied the effect of sugar concentration on orange peel jam [49].

According to SNI, the minimum sugar content in the jam is 55%. The treatment producing the right amount of total sugar content in jam as suggested by SNI was K5 treatment (palm sugar concentration of 60%) and K6 treatment (palm sugar concentration of 70%). The use of palm sugar concentration below 60% will produce jams of which total sugar content is less than the minimum level set by SNI.

3.3. *Total soluble solids in E. cottonii jam.*

The proportion of the combination of both inorganic and organic substances in a food product is commonly known as total soluble solids. Reducing sugar, non-reducing sugar, organic acids, pectin, and protein are components of the soluble solids contained in a food product [50,51]. The total value of soluble solids shows the percentage of an ingredient in a solution, which later remains as a residue resulted from evaporation and heating.

Based on the ANOVA results in Table 2, the information that can be obtained is there was a significant difference between seaweed jam that had different palm sugar concentrations in its ingredients [F (5.18) = 75.542), $p < 0.05$]. Then, based on DMRT results in Table 3, the highest average total soluble solids could be seen in K6 treatment (palm sugar concentration of 70%), with an average value of 54.15% mass fraction. Conversely, the lowest average total soluble solid is seen in K1 treatment (palm sugar concentration of 0%), with an average value of 5.42% mass fraction. The results of Duncan test at the significance level of 5% showed that K6 treatment (palm sugar concentration of 70%) was the best treatment, but it was not significantly different from K5 treatment (palm sugar concentration of 60%) and K4 treatment (palm sugar concentration of 50%). This result is in agreement with previous studies, such as Khan *et al.* [29].

Total soluble solids affect the viscosity of jam [26]. The higher the total soluble solids contained in a product, the more viscous the product will be [52]. Total soluble solids are increasing with the higher addition of sugar concentration during the jam making process. According to Buckle, Edward, Flet, & Wotton (2009), the total soluble solid is higher with the increasing proportion of sugar added as a result of high solubility in sugar [53]. However, the minimum total soluble solids in the jam according to SNI is 65% mass fraction. Thus, this study showed that the total soluble solid in *Eucheuma cottonii Doty* jam was less than the minimum level set by SNI.

3.4. Organoleptic results

Besides water, sugar, as well as soluble solids analysis, the organoleptic tests were also conducted on the seaweed jam produced in this study. The results of the Kruskal-Wallis H test can be seen in Table 4 and the results of the pairwise comparison is presented in Table 5. Based on Table 4, the difference in the percentage of palm sugar concentrations had a significant effect on the results of the seaweed jam's organoleptic test on color parameters [χ^2 (5) = 22.109, p <0.05], aroma [χ^2 (5) = 22.181, p <0.05], taste [χ^2 (5) = 22.225, p <0.05], and texture [χ^2 (5) = 20.242, p <0.05].

Table 4. The summary of the Kruskal-Wallis H test on the effect of palm sugar concentration on color, aroma, taste, and texture of seaweed jam

Sources	Df	Color	Aroma	Taste	Texture
Treatment	5	22.109*	22.181*	22.225*	20.242*

**Significant at 5%*

Table 5. The summary of pairwise comparison through Kruskal-Wallis test adjusted with Bonferroni Correction of the six seaweeds jam produced in this study

Treatment Codes	Color	Aroma	Taste	Texture
K1	2.5a	2.5a	2.5a	2.5a
K2	8.0ab	7.0ab	8.5ab	8.75ab
K3	8.0ab	10.0ab	8.5ab	10.0ab
K4	19.5b	15.0ab	15.5ab	14.0ab
K5	18.0b	19.5b	21.5b	19.3b
K6	18.0b	21.0b	18.5b	20.5b

*Note: Scores followed by the same alphabets show that there is no significant difference on p < 0 .05. *The details of treatment can be seen in Table 1.*

Table 4 shows that the highest average score of organoleptic test for color was found in K6 treatment (palm sugar concentration of 70%). On the other hand, the lowest average score was found in K1 treatment (palm sugar concentration of 0%). The jam produced in K1 treatment (palm sugar concentration of 0%) had whitish brown color. It could be from the original color of raw seaweed used in the jam ingredients. In the treatment where the concentration of palm sugar was added, seaweed jam with brown color was produced as a result of the original color of palm sugar [54].

The increasing of palm sugar concentration added to the jam during the cooking process created darker brown color in *E. cottonii Doty* seaweed jam. The darker color of the jam was resulted from the higher level of sugar concentration added to it, which was also due to the natural potential of the sugar for browning reactions, or commonly known as caramelization [55–57]. Besides that, the heating process leads to the caramelization reaction of sugar and dehydration, which forms brown color [57,58]. In addition, Buckle *et al.* (2009) believed that the brownish color of the food product was caused by caramelization of sugar resulted from high temperature and long cooking [53]. K6 treatment (palm sugar concentration of 70%) was the best and the most preferred treatment for color of *Eucheuma cottonii Doty* seaweed jam. It is seen from the higher average score of organoleptic test for color in K6 treatment compared to other treatments.

Then, Table 4 shows that palm sugar concentration of 70% treatment (K6) obtained the highest average score of aroma parameter, whereas, palm sugar concentration of 0% treatment (K1) obtained the lowest average score. K1 treatment had the lowest score due to the aroma of seaweed remained in the jam, so, most of the panelists did not like it. The seaweed aroma is one of the constraints for some people to consume either fresh or processed seaweed [13]. Organoleptic test score for the aroma of *E. Cottonii* seaweed jam tended to get higher with the increasing level of palm sugar concentration added. This case is mainly due to the effect of palm sugar aroma level. The results of the organoleptic test for aroma showed that the strong aroma of palm sugar could weaken the distinctive aroma of seaweed, which was less preferred by consumers.

In taste parameter, the highest average score of the organoleptic test was found in K6 treatment (palm sugar concentration of 70%), and the lowest average score was in K1 treatment (palm sugar concentration of 0%). The lowest score was obtained as a result of no sugar added to the jam so it did not have a sweet taste. Sugar is usually added to foods to make them more sweet [47,48,59]. In the case of *E. cottonii Doty* jam, the increasing level of palm sugar concentration added will increase the sweetness of jam produced. Usually, foods with a sweeter taste is usually more preferable [47,60,61].

In texture parameter, K6 treatment also had the highest average score, and the lowest average score was found in K1 treatment. The jam produced in K1 treatment had a soft texture, which was caused by the absence of sugar. Without sugar, the free water content rises since the water is not bound by sugar [41–43]. On the contrary, the higher concentration of palm sugar creates thick or viscous jam due to the low water content in it.

4. Conclusion

In this study, seaweed jam made from *E. cottonii* and palm sugar was produced. Several level palm sugar concentrations were used to produce the best quality of jam. The results of this study informed that there was a significant effect of palm sugar concentration level on seaweed jam quality. The best treatment was in the jam with the concentration of palm sugar as high as 70%. In this treatment, the averages of water content, sugar content, and soluble solids content were 33.60%, 64.89%, and 54.15%, respectively.

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