Physical characteristics of instanised chocolate powder sweetened with sucrose produced using continuous and batch type steam jet agglomerator: A preliminary study

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Abstract. Physical properties of instanised chocolate powder are not only determined by processing method, but also influenced by its ingredients. Thus, proportion of ingredients in cocoa drink should be also highly considered. This work investigated the impact of steam jet type and proportion of sucrose on the solubility and appearance of instanised chocolate powder. In this study, two types of steam jet agglomerator, namely continuous and batch type and three levels of sucrose proportion, namely, 15%, 30%, 45% were used as variables. The results showed that the type of Steam jet agglomerator, sucrose proportion and their interaction influenced the parameters investigated. In general, the solubility of instanised chocolate powder produced with continuous type is slightly higher than the solubility of instanised chocolate powder produced with batch type steam jet agglomerator. With regard to the appearance, it can be observed that the brightness of the cocoa drink produced with batch type is slightly lower than that of the cocoa drink produced with continuous type.

1. Introduction

Cocoa (Theobroma cacao L.) is one of the leading commodities of plantations in Indonesia, supported with a large enough plantation area that has excellent potential to be processed. Indonesia is ranked as the third largest cocoa producer in the world after Ivory Coast and Ghana with an average production of 0.75 million tons or contributing up to 16.65% of the world cocoa production [1].

Even though it is one of the leading commodities in Indonesia, cocoa in Indonesia has not been maximally utilized. The use of domestic cocoa beans as raw material for cocoa derivative products is still low. Not only caused by the unavailability of supporting equipment/machinery [2][3], but also due to the lack of knowledge of cocoa farmers about cocoa processing. Cocoa has been exported more in the form of raw beans, causing low added value obtained by the farmers. Therefore, knowledge on improving the quality of cacao derivatives product is important.

The most popular derivative products from cocoa are chocolate biscuits, pralines, chocolate bar, chocolate candy, and chocolate drinks [4][5][6]. Among these products, chocolate drinks are one of the most popular products in Indonesia, especially cold chocolate drinks. This high popularity is supported by the fact that Indonesia has hot weather since it is located in tropical region.

This phenomenon has caused the interest in improving the solubility of cocoa powder in cold water to grow. All this time, chocolate powder found in the market requires warm water for its dissolution. It makes the process of preparing cold chocolate drinks impractical. Therefore, an appropriate small-scale
technology that can produce cold water soluble chocolate powder (instantized cocoa powder) is needed [7].

Agglomeration process using hot steam followed by a drying process is an alternative method that can be used to increase the solubility of chocolate powder [8][9]. Therefore, this study aimed to examine the use of steam jet agglomerator for producing instantized chocolate powder. In this study, the performance of two types of steam jet agglomerator, namely continuous and batch-type agglomerator were assessed. In addition, considering that most people prefer sweetened cold chocolate drinks, the effect of sugar used was also studied. To ensure that sugar can be mixed with cocoa powder homogeneously, icing sugar was used in this study. Icing sugar has the smoothest texture among other type of white sugars derivatives product [10][11]. The parameters tested in this study were moisture content, brightness, and solubility.

2. Methods

2.1 Research Location
This research was conducted at the Laboratory of Food and Postharvest Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada.

2.2 Tools and Materials
The chocolate powder was obtained from Chockless, Yogyakarta. While Gulaku icing sugar was purchased from local supermarkets. Continuous and batch-type steam jet agglomerator were used to produce instantised cocoa powder.

2.3 Sample Preparation
There were three formulations tested in this study Table 1.

| Proportion of Sugar (%) | Sugar Mass (gram) | Chocolate Powder Mass (gram) | Total Mass (gram) |
|------------------------|------------------|-------------------------------|-------------------|
| 15                     | 12               | 68                            | 80                |
| 30                     | 24               | 56                            | 80                |
| 45                     | 36               | 44                            | 80                |

2.3.1 Mixing Material. Before the instantiation process was carried out, the material was mixed homogeneously. The mixing was performed in two stages. The first stage is called pre-mixing and the second stage is called final mixing. Pre-mixing was done by sieving a mixture of chocolate powder and sugar with a 30 mesh sieve. The purpose of this process was to ensure that there are no large lumps of raw instantised chocolate powder material. Final mixing is done with a 58 rpm rotation speed mixer, which was divided into several steps. The first step, 1/3 of the material was inserted and mixed for 90 seconds. Second, another 1/3 of the materials added and mixed for 90 seconds. At the last step, the remaining 1/3 of the material was added and mixed for 60 seconds. This mixing process follows the method described by [12].

2.4 Production of instantised chocolate powder
The instantised chocolate powder production process was obtained using a continuous and batch-type steam jet agglomerator. The production process using a steam jet agglomerator with a continuous type began with heating the water in the steam boiler at a constant pressure of 1 bar, after which the cocoa powder was inserted in the wetting zone inlet [13]. The priciple of batch type steam jet agglomerator was similar to that of steaming. The water was first heated in a pan above which a plate with holes had been installed to place the sample. After the water boiling, the sample was placed in the pan for 90 seconds. The selected time referred to the production process of instantised chocolate powder using the
continuous type. Chocolate powder that had been agglomerated were then dried with tray dryer for 4 hours. This drying was performed to reduce the moisture content in the material so that the material has a long shelf life.

Table 2. Samples of instanised chocolate powder produced with different cycle of agglomeration process and proportion of sugar

| Continuous Type | Proportion of Sugar (%) |  |
|-----------------|-------------------------|---|
| Cycles          | 15                      | 30 | 45 |
| 1               | CG15P1                  | CG30P1 | CG45P1 |
| 2               | CG15P2                  | CG30P2 | CG45P3 |
| 3               | CG15P3                  | CG30P2 | CG45P3 |

| Batch Type      | No Cycle | BG15 | BG30 | BG45 |

2.5 Analysis Method

2.5.1 Moisture content. The moisture content measured was the moisture content before and after drying. Moisture content analysis was carried out using thermogravimetric method. This method has the principle of evaporating water in the material by heating it in the oven. This process is performed until the sample weight is constant [14].

2.5.2 Brightness. Color was measured using a chromameter (Minolta CR-400). CIE L*(lightness component), a*(green to red component), b*(blue to yellow component) system was used for color determination [15]. Prior to the measurement the cacao powder sample was flattened perfectly using a spatula in the sample box. Measurements was done in 3 repetitions.

2.5.3 Solubility. The solubility of instanised chocolate powder is tested by dissolving 0.75 grams of sample (0.4 - 4 mm diameter) in 10 ml of distilled water in a 250 ml measuring cup. For the uniformity of the measurements, the sample was stirred for 5 minutes using a magnetic stirrer and hot plate (SRS710HA, Advantech S072982) at 30°C. The insoluble solids were then deposited using a centrifuge for 15 minutes at a rotation speed of 5000 rpm. Following, the liquid was removed and the precipitated solids were taken with a spatula to dry in the oven for 24 hours at ±105°C. Solubility of the powder was then calculated using equation 1

\[
\% \text{ solubility} = \frac{\text{solids in the supernatant}}{\text{solids in solution}} \times 100\% \quad (1)
\]

Where:
Solids in the supernatant = 0.75 grams - the mass of the solids after oven drying
Solids in solution = 0.75 grams

2.6 Data Analysis
Data analysis was performed using SPSS 21 software. One-way analysis of variance (ANOVA) and Principal Component Analysis (PCA) were used. One-way ANOVA was used to test the effect of moisture content, brightness, and solubility at a significance level of 0.5%, while PCA was used to visualize the relationships between samples.
3. Results and Discussion

3.1 Relationship between Proportion of Icing Sugar and Type of Agglomeration System for Instanised Chocolate Powder

Two-way ANOVA analysis was conducted to determine the effect of the proportion of icing sugar, the agglomeration process cycle, and their interaction with the characteristic parameters of the instanised chocolate powder made with continuous type steam jet agglomerator. Data from the batch type steam jet agglomerator was tested using one-way ANOVA to see the effect of the proportion of icing sugar. In addition, Principal Component Analysis (PCA) was conducted to study the relationship between the characteristic parameters and the type of steam jet agglomerator used.

Based on Table 3., it can be seen that in continuous type steam jet agglomerator, the proportion of icing sugar significantly affected (p<0.05) the moisture content before drying, moisture content after drying, L* value and solubility of the powder. The agglomeration process cycle affected the moisture content before drying and the L* value. While the interaction between the two affected the moisture content after drying and the L* value. In the batch type steam jet agglomerator, the proportion of icing sugar affected the four characteristics of the tested material.

**Table 3. The relationship between the proportion of icing sugar and the type of agglomeration system and their impact on the characteristics of instanised chocolate powder**

| Parameter                  | Moisture content before the Drying Process | Moisture content after the Drying Process | L* | Solubility |
|----------------------------|------------------------------------------|------------------------------------------|----|------------|
| Continuous Type            |                                          |                                          |    |            |
| Icing Sugar (S)            | *)                                       | *)                                       | *  | *          |
| Agglomeration Process      |                                          |                                          |    |            |
| Cycles (C)                 |                                          |                                          |    |            |
| Interaction between S X C  |                                          |                                          | *  | *          |
| Batch Type                 |                                          |                                          |    |            |
| Icing Sugar (S)            | *)                                       | *)                                       | *  | *          |

*) significance on p<0.05

The PCA results (Figure 1.) show that the total variance in the first two principal components (PC 1 and PC 2) was 89%. Solubility value, moisture content before drying and moisture content after drying were mostly influenced by PC 1. While the L* value was more influenced by PC 2. Based on PC 1 (Figure 2.), it can be seen that the solubility value was directly proportional to the moisture content before and after drying. In addition, PC 2 showed that the L* value was directly proportional to the moisture content after drying.

Based on Figure 1. and 2., it can be seen that chocolate produced with continuous type steam jet agglomerator except CG45P3 had a higher color compared to chocolate produced with batch type steam jet agglomerator. It could be due to the fact that the contact between material with hot steam lasts longer and continues to occur in samples produced using the batch type steam jet agglomerator. This phenomenon is believed to cause the dissolution of sugar in the sample, hence the measured color was the color of cocoa solids. From the same figures, it can also be observed that the solubility of samples made with continuous type jet steam agglomerator was higher than that of samples made with batch type steam jet agglomerator. This could be caused by the low sugar losses in the samples prepared with continuous type jet steam agglomerator. This contributed to the higher solubility of the sample considering that sugar is more soluble than cocoa particles.
Figure 1. PCA loading plot of characteristic parameters of instanised chocolate powder produced using continuous and batch type of agglomerator

Figure 2. PC 2 Score plot of instanised chocolate powder produced using steam jet agglomeration

3.2 Moisture content Before the Drying Process
Based on Figure 3., it can be seen that in the continuous type jet steam agglomerator, the number of production cycles and the proportion of icing sugar affected the sample’s moisture content. The more production process cycles applied, the higher the moisture content before drying was. The highest
moisture content of the sample was observed to reach 12%. It is reasonable considering that the samples underwent more agglomeration cycle, they were exposed to hot steam for a longer period of time. The same phenomenon was observed in samples prepared with batch type steam jet agglomerator (Figure 4.). In addition, from Figures 3. and 4., it can also be seen that the higher the proportion of icing sugar, the higher the moisture content of the sample was. It was probably due to the fact that the water attached to the sugar was more difficult to be evaporated compared to that in cocoa particles.

![Figure 3. Moisture content before the drying process in samples prepared with the continous type system](image)

![Figure 4. Moisture content before the drying process in samples processed with the batch type system](image)

### 3.3 Moisture content after Drying Process

The drying process after the agglomeration is aimed to reduce the moisture content of the samples to avoid fungal growth thus can be stored for longer period of time. The drying process is also performed to produce dry and porous samples so that they dissolve easily in cold water. The result (Figure 5.) shows that the agglomeration cycle affected the moisture content after drying. The longer the agglomeration process (more cycle applied), the better the moisture content of the samples will be [16]. However, it can be seen that the difference in moisture content of the samples was not considerable. The range of moisture content fell between 5 - 7.17%. The moisture content of the samples produced with batch type steam agglomerator also increased with increased proportion of icing sugar, with the highest moisture content observed was 2.03% from sample CG15P1. Compared to the moisture content of the samples made with continuous-type steam jet agglomerator, the moisture content of that prepared with batch-type agglomerator had lower moisture content. Sugar dissolution (sugar losses) could be used to explain this phenomenon as it has been mention in section 3.1.
Figure 5. Moisture content after the drying process on the samples processed with a continuous type agglomerator system

Figure 6. Moisture content after the drying process the samples processed with batch type system agglomerator

3.4 Brightness

Figure 7. shows the brightness level (L*) of the samples prepared using a continuous type steam agglomerator system. The agglomeration process cycle and the increasing proportion of icing sugar resulted in lower brightness value. This condition could occur due to increase in moisture content thus the material became wet and dark. In addition, Maillard reaction and caramelization which were possible to occur could cause this phenomenon [17]. This reaction caused the products to be darker contributing to the decrease in the brightness of the product. The highest L* value obtained was 28.53 from sample CG1P1, while the lowest L* value was 21.68 from sample CG45P3. Similarly, higher proportion of sugar in samples produced using batch-type steam jet agglomerator also had a darker color (Figure 8.) a the lowest L* value of 20.71 from sample BG45.

Figure 7. Brightness levels in materials that are processed with a continuous type system

Figure 8. Brightness level in materials processed with a batch type system

3.5 Solubility

Solubility is the ability of a components to dissolve in water [18]. Figure 9. shows that the higher the proportion of icing sugar added to the sample, the higher the solubility of the samples was. However, at the same proportion of icing sugar, the number of the agglomeration cycle process did not affect the solubility of samples. This phenomenon shows that sugar had more dominant role compared to the
agglomeration cycle. It is reasonable considering the fact that sugar is more soluble than cocoa particles, hence the higher the proportion of icing sugar, the higher the solubility level will be [19][20]. Similar conditions occurred in samples prepared with batch-type agglomerator where solubility increased with the addition of sugar (Figure 10.). With the same proportion of sugar, the solubility value of samples made with continuous-type steam jet agglomerator was higher than that of samples prepared using batch-type steam jet agglomerator. It was probably because the duration of steam exposure in batch type was longer than that in the continuous type. Therefore the concentration of sugar in samples processed using the steam jet batch type agglomeration was lower than that processed using the continuous type. The highest solubility value in sample produced using continues type was 65.95% (sample CG45P1). While the highest solubility in steam jet batch type agglomerator was 58% (sample CG15P3). This is supported by Shittu et al (2007)[21]. The author stated that agglomeration process increases product solubility.

![Figure 9. Solubility levels in samples processed with a continuous type system](image1)

![Figure 10. Solubility levels in samples processed with a batch type system](image2)

4. Conclusion
The results of this study showed that the type of steam jet agglomerator used had a significant effect on the characteristic parameters of the material tested. Furthermore, the proportion of sugar was apparently important in increasing the solubility of instanised chocolate powder. Solubility, which was the main parameter of instanised chocolate powder, could be increased by using the continuous type steam jet agglomerator and increasing the proportion of icing sugar.

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