Investigating the performance of Steam Jet Agglomerator as a mean to produce Instanised Cocoa Drink

R A Luthfiyah\textsuperscript{1}, D R Diasti\textsuperscript{1}, E F Dyahningrum\textsuperscript{1}, S Rahayoe \textsuperscript{1} and A D Saputro \textsuperscript{1}

\textsuperscript{1}Deparment of Agricultural and Biosystems Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada

E-mail: arifin_saputro@ugm.ac.id

Abstract. Popularity of cocoa-based drink has been growing since long time ago in tropical countries. Iced cocoa drink is highly consumed due to the fact that the ambient temperature in the tropical region is relatively high. This condition stimulates cocoa drink industries to continuously improve the quality of their products. This work investigated the performance of small-scale steam jet agglomerator used to produce instanised cocoa powder. This small-scale machine is designed to increase the solubility of cocoa powder, thus cocoa powder will be easily solubilised in cold water. In this study, a small-scale steam jet agglomerator was manufactured. Afterwards, the impact of three drying times, namely 60°C, 80°C, 100°C and three levels of agglomeration process cycle, namely 1, 2, 3 cycles as well as their interaction on the solubility and colour of the products was investigated. The results showed that the solubility increased as the number of agglomeration process cycle increased. With regard to the colour, the brightness level decreased as the drying temperature and number of agglomeration process cycle increased.

1. Introduction
Sustainable cocoa production has a significant influence on people in developing countries. This sector supports the livelihoods of around 40-50 million farming communities globally. Up to 2014, Indonesia was still the world's third-largest cocoa producer and exporter \cite{1}. Therefore, cocoa market opportunities in Indonesia, for both export and domestic are still very big. However, this high production is not accompanied by improvement of its final products quality. This condition causes the Indonesian government to implement the Export Duty (BK) policy on the export of cocoa beans, which is intended to reduce the volume of cocoa bean exports. This policy influences the growing of new cocoa processing industries.

Some cocoa-based products that are popular in Indonesia are chocolate candy, chocolate bars, ice cream and chocolate drinks. Chocolate drink is a derivative product of cocoa, which is currently the most popular one in Indonesia. This is due to the fact that Indonesia is a tropical country, thus people prefer to drink ice chocolate compared to other cocoa derivative products. It is similar to conditions in several other cocoa producing countries such as Nigeria, Ghana, Trinidad and Tobago \cite{2}.

Chocolate beverage products are generally prepared from cocoa powder and sugar with the addition of other ingredients such as milk, flavouring agents, minerals and vitamins which are mixed and agglomerated \cite{3-5}. Cocoa powder still contains at least 10-11% of fat, thus in the process of making chocolate drink, hot water is needed to help solubilizing the powder. This is not practical considering that chocolate drinks is normally served cold in Indonesia. In addition, because the particle size is quite
large, the cocoa powder particles will settle after a while. To overcome this problem, large companies use stabilizers to keep the chocolate drinks homogeneous. However, for a small-medium scale producers, the addition of stabilizers will increase the production costs, which will burden producers, especially small-medium scale producers. Therefore, a method is needed to solve the problem mentioned above [6]. Agglomeration is an alternative process that can be used to improve reconstitution properties of cocoa powder in liquid [7]. The production of cocoa powder is simple yet complex process. The process of making instant chocolate drink can be performed with fluid bed agglomeration [8], and steam agglomeration [9-12]. High shear mixer has also been used for wet granulation of cocoa powder [13].

Based on the explanation above, it requires innovation and appropriate technology for cocoa powder production suitable for small-medium scale producers. With this technology, small and medium scale producers are expected to be able to process and produce cocoa-based drinks independently at low cost. Besides, it is expected that the obtained products from small and medium scale producers can compete with that from big company. One of the technologies that can be applied is the use of small-scale "steam jet agglomeration". The use of this machine will increase the solubility of chocolate beverages, which makes the preparation of chocolate drinks to be easier, without any hot water required. This study aimed to examine the performance of steam jet agglomeration machines. The research variables used were the drying temperature and the cycle of agglomeration process. The measured quality parameters of the instant chocolate beverage were moisture content, solubility and colour.

2. Material and Method

2.1. Location
The research was conducted at the food and post-harvest engineering laboratory, Gadjah Mada University, Yogyakarta, Indonesia.

2.2. Raw material
The material used in this study consisted of cocoa powder with 27% fat content obtained from the Indonesia Coffee and Cocoa Research Center, Jember, East Java.

2.3. Sample preparation
Characterization of cocoa powder raw material was carried out prior to the production of instant chocolate beverage. Moisture content and the colour of the cocoa powder were determined.

| Table 1. | Samples of instantised chocolate powder produced with different cycle of agglomeration process and drying temperature |
| Drying Temperature (°C) | Cycle of agglomeration process |
|--------------------------|------------------------------|
|                          | 1P60T | 2P60T | 3P60T |
| 60                       | 1P60T | 2P60T | 3P60T |
| 80                       | 1P80T | 2P80T | 3P80T |
| 100                      | 1P100T| 2P100T| 3P100T|

2.4. Instantized chocolate powder production
The process of producing instant chocolate beverage was performed using steam jet agglomerator. Drying temperature and cycle of agglomeration process were used as research variables. The mass of cocoa powder used in this study was 80 gr. The production process begins by heating the water in the steam boiler at a constant pressure of 1 bar. Subsequently, the cocoa powder was poured into the wetting zone inlet. The process of repeating the agglomeration is carried out for once, twice, and three times,
for each sample of cocoa powder. After that, the sample was dried using three different temperatures, namely 60°C, 80°C, dan 100 °C for 8 hours. Table 1 shows the samples prepared in this study.

2.5. Analysis method
2.5.1. Moisture content. Measurement of water content was carried out by the thermogravimetric method [14]. The measurement was started by weighing the mass of the empty cup (W₀). Following, 1 gram of the sample was put into the aluminium cup (W₁). The sample was then put into the oven for 24 hours at ± 105°C. After that, the sample was cooled in a desiccator for 15 minutes. The cup filled with sample was then weighed (W₂). Measurements were made in 3 repetitions. The moisture content of dry base material can then be calculated with equation 1

\[
\% \text{ Moisture Content (db)} = \left( \frac{W_1 - W_2}{W_1 - W_0} \right) \times 100\% \tag{1}
\]

2.5.2. Colour. Colour measurement (CIE, L * a * b * system) was done using chromameter (CR-400, MINOLTA). The cocoa powder to be tested was placed in the black preparation box. Before the surface measurement, the cocoa powder sample was flattened with a spatula. Colour measurement was carried out in a closed box to have a constant intensity of light. Measurements were made in 3 repetitions.

2.5.3. Solubility. Solubility test was carried out by dissolving 0.75 grams of cocoa powder (0.4 - 4 mm diameter) in 10 ml of distilled water in a 250 ml cup. For uniform measurement, the sample was stirred using a magnetic stirrer and hot plate (SRS710HA, advantec S072982) at 30°C. Stirring was performed for 5 minutes. After that, the solution was put into a test tube and centrifuged for 15 minutes at 5000 rpm. Afterwards, the liquid was removed and the sediment was taken with a spatula, put into an aluminium cup, and heated for 24 hours at ± 105°C. The solubility of the sample can be then calculated using equation 2

\[
\% \text{ solubility} = \left( \frac{\text{solids in the supernatant}}{\text{solids in solution}} \right) \times 100\% \tag{2}
\]

Where:
- Solids in the supernatant = 0.75 grams - the mass of the solids produced by the oven in 24 hours
- Solids in solution = 0.75 grams

2.6. Statistical analysis
Statistical analysis was performed using SPSS 21.0. One-way analysis of variance (ANOVA) was used to test the effect of variables on the measured parameters (5% significance level). Three-way ANOVA test was performed to determine the interaction between treatments. Before the ANOVA test was carried out, the homogeneity test was performed using Leven's test. Furthermore, when the homogeneity conditions are met, the Tukey test was used to determine the differences between samples. In addition, principal component analysis (PCA) was used to visualize the relationship between samples.

3. Result and discussion
3.1. Characteristics of the cocoa powder
Raw material characterization is the first step that must be done to know the nature and the appropriate handling required in order to obtain product with the desired properties. The moisture content and colour of the cocoa powder used in this study can be seen in Table 2.
Table 2. Characteristic of Cocoa Powder

| Cocoa powder | Moisture (%) | Colour |
|--------------|-------------|--------|
|               | L*          | a*     | b*     |
| 1.4 ± 0.69   | 41.67 ± 0.39| 13.25 ± 0.14 | 23.65 ± 0.18 |

In general, the cocoa powder used had met the standard requirements of the cocoa powder quality found in SNI 2009. The water content of cocoa powder used was relatively low, thus the possibility of bacteria, mould, and yeast to grow was limited. The growth of fungi and other microorganisms can cause changes in the quality of cocoa powder [15]. The cocoa powder used had a high L* (lightness) value, which indicated that the cocoa powder was rather bright. The color of the cocoa powder will affect the color of the chocolate drink produced. According to Afoakwa (2010), good quality chocolate has light to dark brown color [16].

3.2. The influence of drying temperature and cycle of agglomeration process

The drying temperature and cycle of agglomeration process were the two variables used in this study. Both of these variables influenced the characteristics of the instanized chocolate powders produced. The parameters of the instanized chocolate powders studied in this study were water content, solubility and appearance of the instanized chocolate powder. It was found that agglomeration with more cycle caused the particle size of the cocoa powder to be larger, while the drying temperature hanged the shape and size of the powder to be more spongy.

In this study, the interaction between these the treatment was analyzed statistically using two-way ANOVA and principal component analysis. This information is important as it influences the development / optimization of the production system using jet agglomerator. The results can be seen in Table 3

Table 3. Interconnection between drying temperature and cycle of agglomeration process to the characteristics of instanized chocolate powders produced using steam jet agglomerator

| Experimental Variables | Initial moisture content (%) | After drying process moisture content (%) | L* | a* | b* | Solubility (%) |
|------------------------|-----------------------------|------------------------------------------|----|----|----|----------------|
| Temperature (T)        | *                           | *                                        | *  | *  | *  |                |
| Cycle Process (P)      | *                           | *                                        | *  | *  | *  |                |
| Interaction T X P      | *                           | *                                        | *  | *  | *  |                |

*) Significant at p< 0.05

Based on table 3 it can be seen that the initial moisture content was significantly (p <0.05) influenced by the drying temperature, the cycle of agglomeration process and the interaction of the drying temperature with the cycle of agglomeration process. On the other hand, the final moisture content was not affected by the drying temperature. This phenomenon might be due to the fact that the dryer used was modified drying oven, hence it was possible that the circulation of the air was not optimum. As for color, the result indicated that color was influenced by temperature and interaction of the two variables (p <0.05). Meanwhile, the level of solubility was significantly influenced only by the interaction between the temperature and the agglomeration cycle (p <0.05).

The result of the PCA shown in Figure 1 shows the relationship between all parameters of instanized chocolate powder in general. It can be seen that there were two components that explained more than 76.1% of the variance, namely PC 1: 49% and PC 2: 27.1%. In addition it was found that PC 1 was more
dominant than PC 2. Based on PC 1, it can be seen that there was direct proportional relationship between the value of the initial moisture content, the final moisture content, and the level of solubility. However, these parameters were inversely proportional to the level of lightness (L*). This means that the higher the value of the water content before, water content after, and solubility, the lower the value of L* will be (the darker). On the other hand, based on PC 2 it can be seen that the values of a and b were directly proportional.

Figure 1. PCA loading plots of characteristics parameters of instanized chocolate powder

Figure 2. PCA score plots of instanized chocolate powder produced using steam jet agglomeration

3.3. Moisture Content
Moisture content is the percentage of water contained in a material. The initial moisture content was measured after the agglomeration process but before the drying process, while the final moisture content was measured after 8 hours of drying process. The decrease in moisture content of instanized chocolate powder samples was intended to maintain the quality of the instanized chocolate powder so that it has longer shelf life.
Figure 3 and 4 shows the phenomenon that the more the agglomeration cycle, the higher the moisture content level was. The increased in moisture content can increase the size of the chocolate powder granule. After the drying process, the instanized cocoa powder granules become porous and easily distegrated. This condition was thought to improve the solubility properties of instant chocolate powder. From the same figure, it can be seen that the dryer temperature did not significantly affect the moisture content of the sample (p <0.05). This was most probably because of the sufficient drying duration applied to the powder. Even though it used the lowest temperature (60°C).

![Figure 3](image1.png)  
**Figure 3.** Initial moisture content of instanised chocolate powder produced using continuous-type steam jet agglomerator

![Figure 4](image2.png)  
**Figure 4.** Final moisture content of instanised chocolate powder produced using continuous-type steam jet agglomerator after drying process for 8 hours

3.4. Color

Color is one of the most important food quality attributes aside from glossiness, shape, surface and smoothness or roughness [17][18]. Some consumers decide to consume food/drinks based on the colors they see. Product with high nutritional value, good taste, and good texture will be less appealing without attractive color [19]. Color is included as one of important parameters of chocolate quality because it affects the acceptance of the product [20]. Figure 6 show the L* value of the product influenced by the dryer temperature.

Figures 5, 6, 7, 8, 9 and 10 indicate that higher drying temperature and more agglomeration cycle resulted in decrease of the brightness level of cocoa powder (color parameter L*), increase of red color (parameter a*) and intensification of yellow color (parameter b*). The final product tended to be darker which could be due to the influence of heat coming from the continuous-type steam jet agglomerator and high temperature drying process. Similar results were also shown in a study carried out by Shittu and Lawal(2007)[2]. The authors reported that there was a decrease in the product brightness level due to Maillard reaction. In addition, the diameter of the cocoa powder particles also affect the lightness of the product. Small particle size creates more interaction and spread resulting in a lighter color [21][22][23].
Figure 5. Change in L* due to cycle of agglomeration process.

Figure 6. L* change due to drying temperature.

Figure 7. Change in a* due to drying temperature.

Figure 8. Change in b* due to drying temperature.
3.5. Solubility
Solubility is the maximum amount of a substance that can be dissolved in a certain amount of solvents or solution at a certain temperature. Water serves as material that can disperse various compounds in food ingredients. For some ingredients, water acts as a solvent. Heating can reduce the forces of attraction between water molecules and provide adequate energy to the water molecule so it can overcome the forces of attraction between molecules.

Figure 11 depicts the relationship between agglomeration cycle and solubility of the powder. It was observed that agglomeration with more cycle resulted in powder with higher solubility. The more the powder undergo agglomeration cycle, the longer the cocoa powder is exposed to hot steam. This condition will increase the size, porosity, and fragility of the granule. This is supported by Warnida’s statement (2010) that the greater the porosity of the granules, the faster the powder dissolved in water [24].

Furthermore, there are other effects that cause the solubility level to increase, namely the water content of the instant cocoa powder. The higher the water content, the smaller the solubility of the product. The formation of hard-textured granule agglomeration can be used to explain this phenomenon. This causes the time needed to break the bonds between particles to be longer, reducing the solubility of the powder.

Figure 9. change in a* due to cycle of agglomeration process

Figure 10. change in b* due to cycle of agglomeration process

Figure 11. Solubility of instanized chocolate beverages
4. Conclusion

The use of a Steam jet agglomerator machine can increase the solubility of chocolate powder drinks at relatively low temperatures. The research results show that the solubility level increases with the increasing number agglomeration cycle. While the brightness level of the color decreases as the agglomeration cycle process increases. Lastly, it can be concluded that steam jet agglomerator has a great potential to be applied by the small-medium scale chocolate drink industry as a tool for making instanized chocolate drink.

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