Determination of Cocoa Powder Quality Produced by Small-Medium Enterprise Using Six Sigma Analysis

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Abstract

Cocoa powder now has become a common craft product of small-medium processing enterprises (SME) in Indonesia. Small-medium enterprises develop processing sequence in smaller quantity compared to big company, nonetheless it must follow the national cocoa powder standard of SNI 3737:2009. The aim of this experiment was to evaluate the SME cocoa process production performance through Six Sigma analysis of the product to comply the standard requirements. The cocoa powder product was evaluated using three critical to quality (CTQ) parameters involving water content, color, and fineness. National standard determined the maximum water content value is 5%, the color is brown or Agtron number 65 and minimum fineness percentage of particle (75 µm) must be 99.5%. This result explain the stability process of SME which is exceeding the control limit value of non-conformity product. Its process capability showing the Sigma value of 2.6 with defect per million value was 126,667. The CTQ parameters which contribute to the high non-conformity are fineness 78.95% and color 21.05%. The rough cocoa powder or fineness affects the highest non-conformity related to the high fat content in cocoa cake as input process and can be revised by upgrading the pressing machine performance.

Keyword: cocoa, cocoa powder, small medium enterprises, Six Sigma

INTRODUCTION

Small medium enterprises (SMEs) are becoming new preferences for craft product processing managed by farmer group or small cooperative, including cocoa processing (Purba et al., 2018). Cocoa powder is one of cocoa intermediate products having large number of consumers in Indonesia, with many derivative products like sweets, cake, ice cream and cookies (Beg et al., 2017). Indonesian national standard set the pure cocoa powder as a product with mandatory standard stipulated with SNI 3747:2009 (Anoraga et al., 2019). Implementation and evaluation of this national standard in particular to SME’s are required, to accomodate the obstacles that probably arising in its processing practices, such as consistency of fineness or acquired color of fully roasted powder evaluated by the processors (Herjanto, 2011). Food safety and narrow contamination is also another reason to mandatory cocoa powder standard to protect the consumer from healthy problems (Cain et al., 2019).

Cocoa powder is generated by pressing of cocoa mass, resulting extracted cocoa butter and cocoa cake as the rest. Grinding of cocoa cake will result in cocoa powder.
Power capacity and operational setting temperature of pressing machine determine fat content in cocoa cake, which can affect to powdering process performance afterwards (Beg et al., 2017). Quality requirements of cocoa powder described on Indonesian national standard SNI 3747:2009 mostly include the aspect of physical appearance such as fineness, aroma, and color but also contamination of heavy metals and microorganisms (Singh & Barak, 2019). However, the output product is not the only one parameter used to determine the effectiveness but also how its product specification comply to the consumer satisfaction. Quality parameters are also defined as both of how its product specification fulfill consumers satisfaction and preventing the product to become out of standard (Akhmad, 2018). Quality control are essential to maintain technical aspects of production process in conjuction with management interaction (Gleeson et al., 2019). The parameter of quality control consists of quality control of raw material, control of work in process and quality control of final product (Sangshetti et al., 2017).

Quality improvement tools are objected to check and analyze statistically to verify its product conformity to predetermined standard. Six Sigma is an improvement quality statistic tools using population deviation standard (σ) to evaluate and control uniformity (Soemohadiwijoyo, 2018). The six number of Sigma (6σ) indicated the highest variance to be considered, therefore its non conformity probability product have to be controlled in 3.4 per million product capacity, or the cost expectation of poor quality not exceeding of 1% of the total revenue, higher than average value of 15-25% applied in established industry. Assesment method of Six Sigma was conducted by defining, measuring, analyzing, improving, and controlling which can be explained as quantitative and qualitative results (Yadav & Sukhwani, 2016). The aim of this work was to study the out-of-specification product or defect per million opportunity from the SME’s cocoa powder production in Jember with critical to quality (CTQ) defined by national standard parameters and to describe the process improvement to fulfill the SNI 3747:2009 requirements.

**MATERIALS AND METHODS**

**Sample Preparation**

Cocoa powder was obtained from cocoa powder production line in a SME at Jember with processing procedure as described by Mulato et al. (2010), applied for maximum capacity 200 kg.day⁻¹ of raw beans with water content 7-7.5%. Fermented cocoa beans originated from Jember regency were roasted in temperature 120°C for 25 minutes (with 15 minutes cooling time), grinded into particle size 350-400 µm and pressed to separate cocoa butter with pressing machine to gain cocoa cake with fat content of 26.37%. Powdering and sieving process were held on room temperature of 25°C in line with tempering machine by stored in refrigerator for 24 hours in 15°C before packing using sachet machine of 25 g.each⁻¹. Samples were collected from production process every week for 20 times of samplings or replications, since December 2018 until May 2019. Each collection consisted of 10 sachets selected from random pack with 200 total samples. Production capacity reached 15,000 sachets per month and sample quantity was determined from Slovin Equation (Ryan, 2013).

**Physical Quality Evaluation**

Quality evaluation of cocoa powder according to Indonesian national standard, SNI 3747:2009 comply to three parameters of measurement consist of color, water content and fineness stated with the percentage of 75 µm of particle size. These parameters were selected based
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on the critical control point of its process. The critical control point parameter in form of Critical To Quality (CTQ) in Six Sigma analysis.

a. Color Evaluation

A sachet of cocoa powder (25 g) was poured and spread into plate then its powder color was determined using Agtron Standard (Figure 1). The Agtron 65 was used as the control standard which color explained as brown (American type), otherwise Agtron 75 described as light brown, Agtron 55 as dark brown, and Agtron 45 as black very shiny (Pugash, 1995). SNI 3747:2009 point 4.1 does not clearly define the brown color in exact classification. The Agtron number standard adopted from coffee color evaluation is developed by Specialty Coffee Association of America (SCAA) to control the roasting condition or brown color of its powder. Agtron 65 are selected as the optimum roasting color of cocoa powder to obtain natural brown and to prevent the volatile aroma for being exposed excessively.

b. Water Content

The cocoa sample was evaluated according to SNI 3747:2009 standard point 4.1 to control the water content from each production batch. Two grams of cocoa powder in porcelain cup with lid, was put in oven with setting temperature of 100±2°C until constant weight, then placed in desiccator for 30 minutes. Water content was calculated using Equation 1.

\[
\text{Water content} = \left( \frac{m_1 - m_2}{m_0} \right) \times 100\% 
\]

where:
- \( m_0 \) = sample weight (g)
- \( m_1 \) = sample weight before drying (g)
- \( m_2 \) = sample weight after drying (g)

\[ \text{Equation 1} \]

c. Fineness Evaluation

Ten grams cocoa powder were added with one gram of detergent and 20 mL of hot distilled water and stirred until dissolved. Hot distilled water of 280 mL (75±5°C) was added then stirred in hot plate stirrer. The solution was poured into 200 mesh (75 µm) siever and rinse with one litre hot distilled water (75±5°C), then rinse with 25 mL of acetone solution. The siever was moved into watch glass and dried in an oven for 45 minutes in temperature of 103-105°C. The sample was then put in desiccator for 45 minutes. The residue content percentage was calculated by Equation 2.

\[ \text{Equation 2} \]

\( L^* \), \( a^* \), and \( B^* \) are the color coordinates that represent lightness, redness-blueeness, and yellowness-bluiness, respectively.

Figure 1. Agtron standards used in this study
Residue content (%) = \[
\frac{(m_1-m_2)}{m_0} \times 100 \% \tag{2}
\]

Where,
- \( m_0 \) = sample weight (g)
- \( m_1 \) = sample, siever and watch glass weight (g)
- \( m_2 \) = siever and watch glass weight (g)
- Powder content (%) = (100-residue content)%

Six Sigma Analysis

Quality analysis using Six Sigma was conducted by determining the stability and capability process as quantitative tool, while unconformity analysis and improvement procedure treated as qualitative tools. Quantitative output was obtained by plotting the physical quality data of the samples into Pareto diagram and control chart (P-chart) involving upper control limit (UCL), lower control limit (LCL) and center line (CL), which were calculated from Equations 4, 5, and 6. Capability process was evaluated by calculating defect per million opportunity (DPMO) from Equation 6 and Sigma value from Equation 8.

\[
\rho = \frac{np}{n} \tag{3}
\]

\[
CL = \hat{p} = \frac{np}{n} \tag{4}
\]

\[
UCL = \hat{p} + 3\left(\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}\right) \tag{5}
\]

\[
UCL = \hat{p} - 3\left(\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}\right) \tag{6}
\]

\[
DPMO = \frac{\text{total number of defect found in sample}}{\text{sample size x number of defect opportunities per unit sample}} \times 1,000,000 \tag{7}
\]

\[
\text{Sigma level (}\sigma\text{)} = \text{NORMSINV}((10^6-DPMO)/10^6)+1.5 \tag{8}
\]

RESULTS AND DISCUSSION

Stability Process

Craft products are growing rapidly through the SME’s in Indonesia along with the development of small scale machinery invention to utilize the raw material into the final product and arise the added-value at the bottom level of cocoa grower. Cocoa small scale processing, as performed by Manalu et al. (2017), utilize 150 kg of dry beans into final product including cocoa powder. Stability of cocoa powder process in this cocoa production was analyzed by critical to quality (CTQ) regarding to color, water content and fineness parameters as shown in control chart (P-chart) in Figure 2. Proportion of non-conformity sample is beyond the control limit both the UCL and LCL, with highest proportion reaches 0.80 and lowest proportion is 0.20. This result explains that the value of non-conformity sample from 20 samplings is out of control, but the exact parameter of CTQ contribute to the highest proportion have to be confirmed. This process situation regarding to Romdhane et al. (2016) called as point off limits with higher tendency, therefore require production improvement and intervention to adjust the process and to avoid the control limit.

The parameters of CTQ related to high proportion of non conformity sample was shown in Pareto diagram in Figure 3. The standard of SNI 3747:2009 requires the accepted cocoa powder specification which must be brown color, maximum water content is 5% by weight and the minimum percentage of fine particle (75 µm) was 99.5%. Color is critical to expose excessive volatile aroma
during its roasting process, where the darker color might reduce the aroma quality of cocoa powder (Saccheti et al., 2016). High water content shows a deterioration effect during product storage such as the possibility of mold growth or chunk powder affected by its hygroscopic properties (Pereira & Saint'Ana, 2018). The coarse cocoa powder give an effect on steeping session that it can not dissolved well in hot water. Figure 3 shows the non-conformity sample majority contributed by fineness with percentage value gain 78.95% then followed by color with percentage value 21.05%. Cocoa powder production using pressing process regarding to Miguel & Fettermann (2017) might gain 80% of losses around the capacity of 2 tons.month⁻¹. This result stated the probability of non-conformity cocoa product in SME is stay high and may vary depend on its different processing sequence.

**Capability Process**

Capability process describes the company or SME performance to fulfill the standard requirements into the final product. Defect per million opportunity (DPMO) calculated from Equation 7 in conformity to color, water

![Figure 2. Control chart (P-chart) of cocoa powder process](image)

![Figure 3. Pareto diagram of non-conformity cocoa powder product](image)
content and fineness show the number of DPMO are 126,667 units per million product and obtain the Sigma level of 2.6. The highest Sigma level for 6σ is comply to DPMO of 3.4 and the lowest Sigma level for 2σ is comply to DPMO 310,000 (Stamatis, 2019). The Sigma level of cocoa powder processing compared to cake product according to Table 1 signify a big gap although both of them are classified as SME. However, higher capacity of production does not assure its high Sigma level such as reported in ice cream product (Bakti & Kartika, 2020) and cooking oil (Ginting & Ulkhaq, 2018). This cocoa powder capability process is rather low aligned to the common perform of average company in developing countries that could reaches 3σ level (Antony et al., 2007). The main barriers to Six Sigma implementation in developing countries are issues related to culture and resistance to change (Douglas et al., 2017).

Non-Conformity Production

Non-conformity product of fineness (Figure 3) arise during processing in conjunction with operational procedure implementation and machinery. Operational procedure involves human as the operator, processing machine, material and environment which give the possibility that affect the non conformity. Detailed analysis of the cause and effect relation (Figure 4) explains the root causes such as low specification of raw material, not suitable machine specification, the operator ignore in controlling process condition, operational procedure, and processing room, regu-

| Product         | Standard          | DPMO   | Sigma (σ) | Reference                        |
|-----------------|-------------------|--------|-----------|----------------------------------|
| Water process   | SNI 01-3554-2006  | 34,491 | 3.3       | Rimantho, D. & D.M. Mariani, (2017) |
| Ice cream       | SNI 01-3713-1995  | 176,030| 2.4       | Bakti, C.S. & H. Kartika, (2020)  |
| Cooking oil     | SNI 01-2901-2006  | 13,370 | 3.7       | Ginting, E.I. & M. M. Ulkhaq, (2018) |
| Cake/bread      | SNI 01-4309-1996  | 3,480  | 4.5       | Kurniawan, A., Sediono & F. Adinna, (2018) |
| Cocoa powder    | SNI 3747:2009     | 126,667| 2.6       | Present study                     |

Production Improvement

High fat cocoa cake as input material mostly contribute to problem of melting or chunking cake formation during powdering through grinding machine especially on disc mill type. Therefore, the high fat content of cocoa cake of rough powder has to be decreased (Petit et al., 2017). This process does not apply disc type grinder for powdering, but hammer and roll type so that the melting problem does not intensively occur. However, the melted fat could restrain the siever to pass out the fine powder. Cocoa cake as raw material contains 26.37% of fat which in yield pressing process gain
of 53.35% (oil/oil). Pressing machine in this process is operated in 20.7 MPa using hydraulic press type in temperature 60°C. Septianti & Arif (2017), with the same hydraulic type of pressing machine, reported the final yield reached 57.86% (oil/oil) with fat content in cocoa powder obtain 25.13% for operational pressure 30 MPa temperature 50°C. This results reveal that the small scale processing equipped with low pressure of pressing machine (<50 Mpa) result in high fat content cocoa powder, while industrial process can produce low fat cocoa powder less than 10-13% (Joel et al., 2013). Venter et al. (2007) also reported with higher temperature of 70°C with the same pressure of 30 MPa, produced a higher butter yield of 71.90% (oil/oil). In industry, cocoa liquor is pressed at 35 MPa to obtain a yield of 73% fat. Pres-
sures higher than 50 MPa are used to obtain yields of 88% or higher. It is not expected to set pressure above 60 MPa in small scale processing, because it will result in difficult maintenances (Minifie, 1989).

CONCLUSIONS

Non-comformity of cocoa powder used in this research mostly occupied by the rough powder problem which affected by high fat content in cocoa cake as input material. High fat content will become an obstacle in powdering and sieving machine, therefore the fine powder can not attain 99.5% as required in the SNI standard. Temperature of production room are also suggested to be controlled precisely by following the recommended operational procedure.
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