Pelita Perkebunan 37 (2) 2021, XX–XX
ISSN: 0215-0212 / e-ISSN: 2406-9574

Determination of Cocoa Powder Quality in Produced by Small-Medium Enterprises in Jember District using Six Sigma Analysis

Hendy Firmanto[1*)], Yesi Kumalasari[2)], and Zikil Muarrofah[3)]

[1)]Indonesian Coffee and Cocoa Research Institute, Jl. PB Sudirman 90 Jember 68118, Indonesia
[2)]Agroindustial Management, Polytechnic of Jember, Jl. Mastrip, Jember 68121, Indonesia
[3)]Faculty of Agriculture, University of Jember, Jl. Kalimantan 37 Kampus Tegalboto Jember 68121, Indonesia
[*)]Corresponding author: hendy.firmant@gmail.com
Received: .... / Accepted: ....

Abstract

Cocoa powder now has become a common craft product of small-medium enterprises (SME) processing 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 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 of water content value is maximum 5%, the color is brown or Agtron number 65 and minimum finenesss 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 parameter which contribute to the high non-conformity are finenesss 78.95% and color 21.05%. The rough cocoa powder or finenesss 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 product having large number of consumers in Indonesia, with many derivative product 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 finenesss 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 generated from cocoa cake by pressing of cocoa mass is cocoa butter product. 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 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 effectivenes 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.*, 2014).

Quality improvement tools are objected to check and analyze satistically to verify its product conformity to predetermined standard. Six Sigma is an improvement quality statistic tools using population deviation standard (ó) to evaluate and control its uniformity (Soemohadiwijoyo, 2018). The six number of Sigma (6ó) 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 controling (DMAIC) which can be explained as quantitative and qualitative result (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.

MATERIAL AND METHODS

Sample Preparation

Cocoa powder was obtained from cocoa powder production line in "Koperasi SEKAR" 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%. Cocoa beans originated and fermented from Jember regency were roasted in temperature 120^{o}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^{o}C in line with tempering machine by stored in refrigerator for 24 hours in 15^{o}C before packing using sachet machine of 25 g/each. Sample were collected during one month production for 20 times sampling or replication from December 2018 until May 2019, each collection consisted of 10 sachet 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 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 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 to the Agtron Standard was determine (Figure 1). The Agtron 65 are used as the control standard which this color explained as brown (American type), otherwise the Agtron 75 describe as Light brown, Agtron 55 as dark brown, and Agtron 45 as black very shinny (Pugash, 1995). In the 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 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 evaluated according to SNI 3747:2009 standard poin 4.1 to control the water content from each production batch. Two gram of cocoa powder in porcelain cup with lid, was put in oven with setting temperature of 100±2°C until constant weight. Move into desicator for 30 minutes Water content was calculated usig Equation 1:

$$\text{Water content} = \frac{(m1-m2)}{m0} \times 100\% \quad \text{..........} \quad 1$$

m_0 = sample weight (g)
m_1 = sample weight before drying (g)
m_2 = sample weight after drying (g)

c. Fineness Evaluation

Ten gram Cocoa powder for added with one gram of detergent and 20 mL of hot distilled water and stir until dissolved. Hot distilled water of 280 mL (75±5°C) was added then stir in hot plate stirrer. The dilution was poured into 200 mesh (75 µm) siever and rinse with one litre hot distelled 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

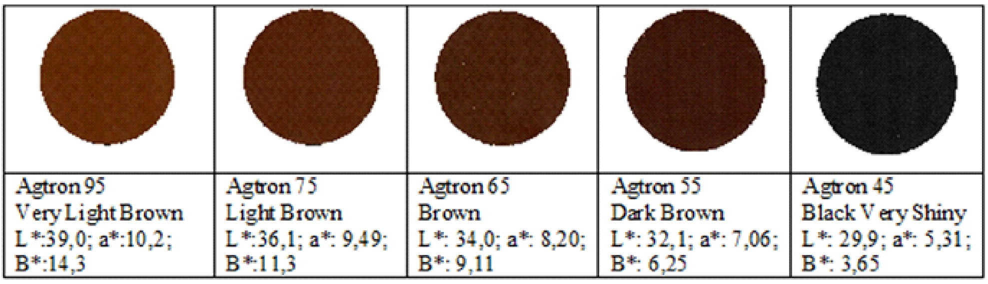

Figure 1. Agtron commercial scale of SCAA

minutes in temperature of 103-105 °C. The sample ws than put in desicator for 45 minutes. The residue content was calculated the percentage by the Equation 2:

$$\text{Residue content (\%)} = \frac{(m1-m2)}{m0} \times 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 2$$

m_0 = sample weight (g)
m_1 = sample, siever and watch glass weigh (g)
m_2 = siever and watch glass weight (g)
powder content (%) = 100% - residue content

Six Sigma Analysis

Quality analysis Using Six Sigma conducted by determining the stability and capability process as quantitative tool, while unconformity analysis and improvement procedure 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 evaluated by calculating defect per million opportunity (DPMO) from Equation 6 and Sigma value from Equation 8. Qualitative output was presented in Ishikawa diagram (Tannady, 2015) or Fishbone diagram. Ishikawa diagram was developed to appoint to cause and effect which accomodate to processing factor such as: man, method, machine, material and environment involved.

$$p = \frac{np}{n} \quad \ldots\ldots\ldots\ldots\ldots\ 3$$

$$CL = \acute{p} = \frac{\Sigma np}{\Sigma n} \quad \ldots\ldots\ldots\ldots\ 4$$

$$UCL = \acute{p} + 3\left(\sqrt{\frac{\acute{p}(1-\acute{p})}{n}}\right) \quad \ldots\ldots\ 5$$

$$UCL = \acute{p} - 3\left(\sqrt{\frac{\acute{p}(1-\acute{p})}{n}}\right) \quad \ldots\ldots\ 6$$

Sigma level (ó) =

NORMSINV((10^6-DPMO)/10^6)+1.5) 8

Where,

p = fraction of non-conforming
np = total non-conforming
n = sample size
U = average proportion of samples with attribute

RESULTS AND DISCUSSION

Stability Process Evaluation

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 sampling 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.

$$DPMO = \left(\frac{\text{total number of defect found in sample}}{\text{sample size x number of defect opportunities per unit in the sample}}\right) x\ 1.000.000 \quad \ldots\ldots\ldots\ 7$$

The parameters of CTQ related to high proportion of non conformity sample was shown in Pareto diagram in Figure 3. The standards of SNI 3747:2009 require the accepted cocoa powder specification wich must be brown color, maximum water content is 5% by weight and the minimum percentage of fine particle (75 µm) was 99.5%. Color was 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 *et al*., 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 (2016) might gain 80% of losses around the capacity of 2 tons/month. This result stated the probability of non-conformity cocoa product in SME is stay high and may vary depend on its different processing sequence.

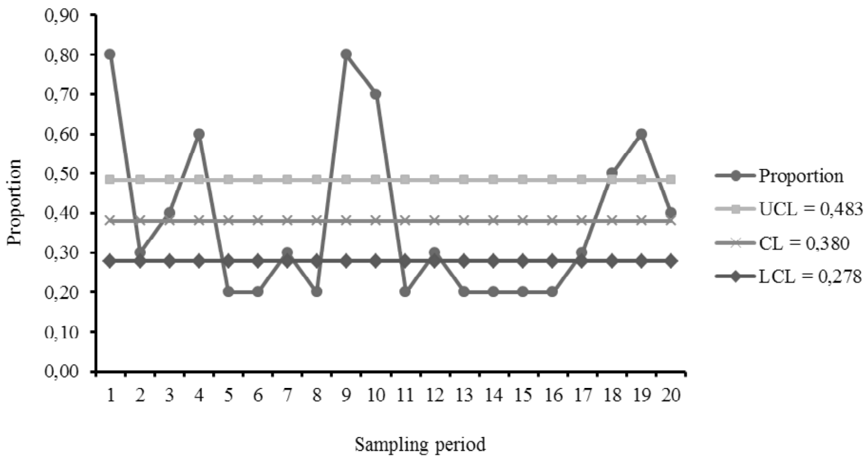

Figure 2. Control chart (P-chart) of cocoa powder proses

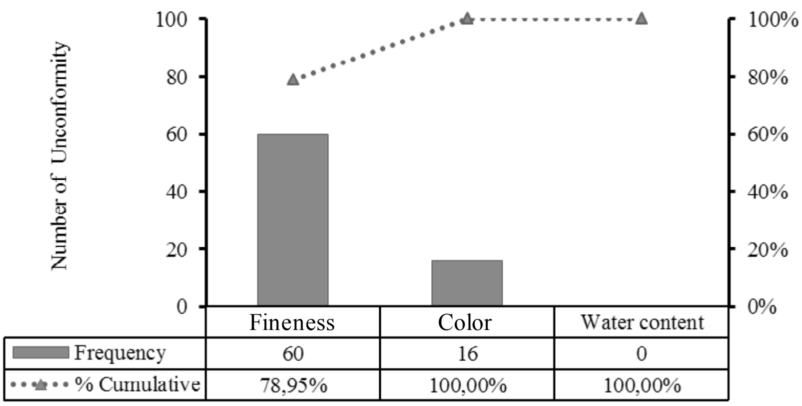

Figure 3. Pareto diagram of non-conformity cocoa powder product

Capability Process Evaluation

Capability process describes the company or SME performance to fullfill the standard requirements into the final product. Defect per million opportunity (DPMO) calculated from Equation 7 in conformity to color, water content and fineness that showing the number of DPMO are 126,667 unit per million product and obtain the Sigma level of 2,6. The highest Sigma level for 6ó is comply to DPMO of 3.4 and the lowest Sigma level for 2ó is comply to DPMO 310,000 (Stamatis, 2019). The Sigma level of cocoa powder processing compare to cake product according to Table 1 signify a big gap although both of them are classified as SME, but higher capacity of production 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 3ó 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 Analysis

Non-conformity product of finenesss (Figure 3) arise during processing in conjuction 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, regularly. Specification of cocoa cake as input material in cocoa powder processing still contains 26.37% fat which is higher than commercial defatted cocoa powder (around 10-12%), in which become main problem during the process (Beckett, 2009). High fat content can be minimized by increasing the pressing machine performance. Environmental factor can may increase the water content during cocoa powder processing due to air humidity condition or room temperature fluctua-

Table 1. Comparison of DPMO value in local food industry towards SNI standard

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

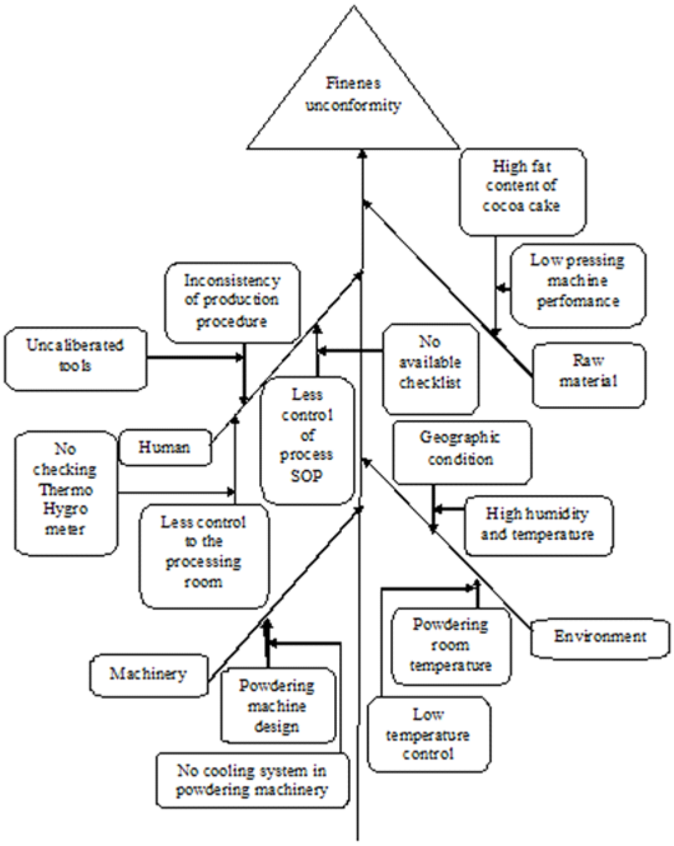

Figure 4. Ishikawa diagram of cause-effect of cocoa powder production ()

tions. Cocoa powder processing machine consists of cake grinding machine and sieving machine which was designed without temperature control appliances and not in accordance with high fat cocoa cake. However, cocoa cake as raw material may vary in terms of its fineness depending on the pressing machine type. Rough powder could affect its solubility that may even tolerable to several consumer acceptance (Afoakwa, 2014).

Production Improvement

High fat cocoa cake as input material mostly contribute in problem of melt or chunk cake formation during powdering through grinding machine especially on disc mill type. Therefore, the high fat content of cocoa cake has to be decreased of rough powder (Petit *et al*., 2017). This process not apply disc type grinder for powdering, but hammer and roll type so that the melting problem not intensively occured. However, the melted fat could restrain the siever to pass out the fine powder. Cocoa cake as raw material contains 26.37% of fat, means that result 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^{o}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 peressure 30 MPa temperature 50^{o}C. This result reveal 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 content cocoa powder, not exceeding 10-13% (Joel *et al*., 2013). Venter (2007) also reported with higher temperature of 70^{o}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. Pressures 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, become it will result in difficult maintenances (Minifie, 1989).

CONCLUSION

Production process of cocoa powder in Koperasi SEKAR of Jember shows less control as revealed by high non-conformity due to defect per million (DPMO) value of 126,667 and Sigma value (ó) of 2,6. Non-comformity product 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. This is probably due to the limited ability of the hydraulic press machine to filter the fine cocoa liquor. Temperature of production room are also suggested to be controlled precisely by following the recommended operational procedure.

REFERENCES

Afoakwa, E.O. (2014). *Cocoa Production and Processing Technology*. CRC Press, USA.

Akhmad (2018). *Manajemen Operasi: Teori dan Aplikasi dalam Dunia Bisnis*. Azkiya Publishing, Bogor.

Anoraga, S.B.; S. Wijanarti; I. Sabarisman & A.R. Sari (2019). Optimization of temperature and time extraction for cocoa powder production on small scale farmers. *Jurnal Ilmiah Rekayasa Pertanian dan Biosistem*, 7(1), 85–94.

Antony, J.; F.J. Antony; M. Kumar & B.R. Cho (2007). Six Sigma in service organisations. *International Journal of Quality & Reliability Management*, 24(3), 294–311.

Bakti, C.S. & H. Kartika (2020). Analisa pengendalian kualitas produk ice cream dengan metode Six Sigma. *Journal of Industrial Engineering & Management Research,* 1(1), 63–69.

Beckett, S.T. (2009). *Industrial Chocolate Manufacture and Use,* 4th Ed. John Wiley and Sons, United Kingdom.

Beg, M.S.; S. Ahmad; J. Kulsum & B. Khalid (2017). Status, supply chain and processing of cocoa: A Review. *Trends in Food Science and Technology*, 66, 108–116.

Cain, N.; O. Alka; T. Segelke; K. von Wuthenau; O. Kohlbacher & M. Fischer (2019). Food fingerprinting: Mass spectrometric determination of the cocoa shell content (*Theobroma cacao* L.) in cocoa products by HPLC-TOF-MS. *Food Chemistry*, 298, 125013.

Douglas, J.; D. Muturi; A. Douglas & J. Ochieng (2017). The role of organisational climate in readiness for change to lean Six Sigma. *The QTM Journal*, 29(5), 666–676.

Ginting, E.I. & M.M. Ulkhaq (2018). Analysis of ice cream product quality control with Six Sigma method. *Industrial Engineering Online Journal*, 7(1), 63–69.

Gleeson, F.; P. Coughlan; L. Goodman; A. Newell & V. Hargaden (2019). Improving manufacturing productivity by combining cognitive engineering and lean Six Sigma Methods. *Procedia CIRP*, 81, 641–646.

Herjanto, E. (2011). Mandatory Application Of SNI in industrial sector: Effectivity and aspects in its implementation. *Jurnal Riset Industri*, V(2), 121–130.

Joel, N.; B. Pius; A. Deborah & U. Chris (2013). Production and quality evaluation of cocoa products (plain cocoa powder and chocolate). *American Journal of Food and Nutrition*, 3(1), 31–38.

Kurniawan, A.; Sediono & F. Adinna (2018). Analisis pengendalian kualitas proses produksi kue lapis kukus surabaya berdasarkan metode Six Sigma. *Statistika Journal*, 18(1), 21–29.

Manalu, L.P., M.Y. Djafar; T.Y. Wibawa & H. Adinegoro (2017). a case study of SME cocoa by-pass processing in Luwu, South Sulawesi. *Majalah Ilmiah Pengkajian Industri*, 11(1), 51–60.

Miguel, V.C. & D.C. Fettermann (2017). Use of DMAIC as a tool for loss reduction: an application in cocoa processing. *Journal of Lean Systems*, 2(1), 52–67.

Minifie, B.W. (1989). *Chocolate, Cocoa and Confectionary: Science and Technology*. Chapman and Hall: London

Pereira, A.P.M. & A.S. Sant'Ana (2018). Diversity and fate of spore forming bacteria in cocoa powder, milk powder, starch and sugar during processing: A review. *Trends in Food Science and Technology*, 76, 101–118.

Petit, J.; F. Michaux; C. Jacquota; E.C. Montes; J. Dupas; V. Girard; A. Gianfrancesco; J. Scher & C. Giani (2017). Storage-induced caking of cocoa powder. *Journal of Food Engineering*, 199, 42–53.

Pugash, M. (1995). The roast color classification system: Technology designed to advance the art and science of coffee roasting. *Tea and Coffee Trade Journal*, 167(7), 66–74.

Purba, H.H.; M.S. Maarif; I. Yuliasih & A. Hermawan (2018). Single origin: the potential of market innovation for increasing the competitiveness of SMEs in chocolate industry in Indonesia. *International Journal of Engineering Research and Advanced Technology*, IV(5), 63–71.

Rimantho, D. & D.M. Mariani (2017). Penerapan metode Six Sigma pada pengendalian kualitas air baku pada produksi makanan. *Jurnal Ilmiah Teknik Industri*, 16(1), 1–12.

Romdhane, T.B.; A. Badreddine & M. Sansa (2016). A new model to implement Six Sigma in small-and medium-sized enterprises. *International Journal of Production Research*, 55(15), 4319–4340.

Ryan, T. (2013). *Sample Size Determination and Power*. John Wiley and Sons, New Jersey.

Sacchetti, G.; F. Ioannone; M. De Gregorio; C. Di Mattia; M. Serafini & D. Mastrocola (2016). Non-enzymatic browning during cocoa roasting as affected by processing time and temperature. *Journal of Food Engineering*, 169, 44–52.

Sangshetti, J.N.; M. Deshpande; Z.D.B. ZaheerShinde & R. Arote (2017). Quality by design approach: Regulatory need. *Arabian Journal of Chemistry*, 10, S3412–S3425.

Septianti, E. & A. Arif (2017). Effect of cocoa liquor temperature to the yield and fat content of cocoa powder fermented and unfermented cocoa. *Jurnal Penelitian Pascapanen Pertanian*, 13(1), 43–51.

Singh, M. & S. Barak (2019). *Cocoa and Chocolate Based Beverages*. Scientific Publisher, Jodhpur.

Soemohadiwidjojo, A.T. (2018). *Six Sigma: Metode Pengukuran Kinerja Perusahaan Berbasis Statistik*. Penebar Swadaya (Jakarta).

Stamatis, D.H. (2019). *Six Sigma Fundamentals: A Complete Introduction to the System, Methods, and Tools*. CRC Press, New York.

Tannady, H. (2015). *Pengendalian Kualitas*. Graha Ilmu, Yogyakarta.

Yadav, A. & V.K. Sukhwani (2016). Quality improvement by using Six Sigma DMAIC in an industry. *International Journal of Current Engineering and Technology*, 6(6), 41–46.

Venter, M.J.; N. Schouten; R. Hink; N.J.M. Kuipers & A.B. de Haan (2007). Expression of cocoa butter from cocoa nibs. *Separation and Purification Technology*, 55, 256–264.