Optimization of the hydrogenation and rafination process for cocoa butter substitute production using palm kernel oil in a small and medium scale industry

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Abstract. The study on the optimization of hydrogenation and rafination process for cocoa butter substitute (CBS) production using palm kernel oil in small and medium scale industry was conducted. The CBS production process included: hydrogenation, cooling, bleaching, filtering, deodorizing, cooling, and packaging. The optimum condition of the hydrogenation process was obtained using hydrogen with 0.2% nickel catalyst, at 195-200°C, under 2-2.5 bar, using 6.12 hz agitation at 1700 rpm, for 12 hours process. The optimum condition of the rafination process was achieved by bleaching using 2% bentonite at 80-95°C for 45 minutes and cooling it at 60°C, and deodorizing it at 240°C for 4 hours. The final product of CBS had similar quality characteristics as commercial cocoa butter and was well accepted by consumers. It contained no trans-fatty-acid, 0 nickel, low FFA, and a melting point of 37.1°C.

1. Introduction
Cocoa butter is usually used for the production of chocolates, coatings, and confectionery fillings. Cocoa butter has a unique characteristic that is solid at room temperature and melts quickly above 30-32°C [1,2]. This behavior produces a stable confectionery product that releases flavors in the mouth at body temperature without any undesirable waxy texture. Cocoa butter consists of three main triacylglycerols [1,3]. These triacylglycerols dominate the melting characteristic and solid fat content as a function of temperature and polymorphic transformations of chocolate, providing chocolate’s textural and sensory properties [4,5].

Because cocoa butter is very expensive compared to other commercial vegetable fats and oils, many manufacturers are looking for alternatives to cocoa butter [2,6]. Cocoa butter alternatives consist of three categories: cocoa butter substitutes (CBS) produced from lauric fats, cocoa butter replacers (CBR) produced from the hydrogenation of vegetable oils, and cocoa butter equivalents (CBE) produced from polymorphic and non-lauric fats [2,7]. Among them, CBS is generally used in confectionery fillings such as compound chocolates and other confectionery products [8,9].

Crude palm kernel oil contains non-triacylglycerol components that must be partially or totally removed to become acceptable for human consumption. Crude oil is therefore submitted to several treatments whose objective is to remove the objectionable minor components with the least possible damage to the oil fraction and minimal losses of desirable constituents [10].

Today, palm oil is the largest source of vegetable oil needed by many industries in the world. Indonesia, as the largest producer of palm oil in the world, has an advantage in terms of resources...
compared to other palm oil-producing countries. Palm oil and its derivatives are widely used in the manufacturing of edible oils, margarine and softeners, ice cream, and dairy products [11].

The chocolate processing industry is one of the food industries which is quite promising. However, in its development, several obstacles must be faced by the chocolate processing industry, one of which is the supply of cocoa butter. As one of the main raw materials in the chocolate processing industry, cocoa butter is used as a raw material for chocolate products such as chocolate bars, chocolate spreads, chocolate coatings, and others. Cocoa fat used in chocolate processing affects the composition of the fat fraction in the chocolate formulation. The fat fraction in the chocolate formulation provides an important role in determining the texture, appearance, and handling of the process and product storage.

The fat fraction in chocolate products is mostly derived from cocoa fat and milk fat. Cocoa butter is the best fat for chocolate products. However, there are several limitations regarding the use of cocoa butter, including unstable supply, relatively high price between natural fats and oils, inadequate use in hot climate areas, and varying qualities. Besides, the tempering process is needed for chocolate products that fully use cocoa butter in its formulation, because it will tend to experience blooming (the outer layer is white like moldy). Therefore, various attempts have been made to develop special fats as an alternative to the use of cocoa butter, one of which is CBS.

CBS has a high content of C 12 : 0 fatty acids (lauric acid). CBS laurate is generally produced from high-fat laurate which is generally produced from the tropics, such as coconut oil and palm kernel oil (PKO) produced from palm oil. The advantages of CBS include: having good oxidative stability (thus providing a longer shelf life), good eating quality, good quality release flavor, not giving a waxy sensation (no waxy after taste), and a very similar texture to chocolates. CBS can solidify quickly, providing good gloss quality and gloss retention, and most importantly CBS is available at a much cheaper price than the cocoa butter price. With all the advantages of CBS, the processing of palm kernel oil into CBS will increase along with the increasing market demand and the advance of oil processing engineering technology.

Hydrogenation is a process to change fat liquid oil into semi-plastic solid that can be used as margarine, special cooking oil, and other special products such as cocoa butter substitute. Hydrogenation is a saturation process to increase oxidative stability and melting points. In the hydrogenation process, hydrogen is reacted with the unsaturated double bonds contained in fatty acids. Oils have been hydrogenated since the 1930s to prolong their shelf life stability [12-14]. Depending on the level of the hydrogenation, oil can be modified into various oils with a variety of hardness. By controlling the PKO hydrogenation process (melting point around 27-28°C), hydrogenated products can be produced with various melting points, ranging from 32-41°C [14]. The chemical, physical and sensory properties of the final product strongly depend on the number of residual double bonds and on the contents of cis-trans isomers present in the mixture [14], which depend on various operating factors, including temperature, hydrogen pressure, catalyst, and circulation rate [16]. The effect of temperature on the hydrogenation has clearly been observed. Hydrogenation, like other chemical reactions, is accelerated by increasing the temperature [17]. Hydrogenated oil is more stable and does not become rancid as quickly as the unhydrogenated oil [18]. It has a higher melting point, and it is often used in frying and pastries for this reason. The basic hydrogenation process of edible oils means that the liquid oils change into semi-solid substances, which have desired melting characteristics and partially hydrogenated oils with increased stability [19].

The hydrogenation process is usually carried out in a three-phase semi-batch reactor where hydrogen gas is bubbled with pressure in hot vegetable fat in the presence of a catalyst [20]. The hydrogenation of edible oils is an important process in the fat industry because of its wide applications to produce margarine, shortenings, and frying oils [18,21].

Hydrogenated CBS generally still has free fatty acids, unpleasant odors, and high nickel residues. All these three constraints can be minimized by the process of rafination (refinement), generally used in physics including degumming, bleaching, and deodorization [22].
The research aims to develop the optimum hydrogenation and rafination process for the production of CBS from Refined Bleached Deodorized Palm Kernel Oil (RBDPKO) as a raw material for compound chocolate.

2. Materials and methods

2.1. Materials

Materials used in this study were RBDPKO (produced by Indonesian Palm Oil Research Institute), nickel, bentonite, and chemicals for analysis obtained from a chemical store in Bogor.

![Diagram of CBS production process]

**Figure 1.** The process of CBS production.
2.2. Equipment
Pieces of equipment used in this study consisted of the pressurized hydrogenation reactor tank and the rafination equipment (bleaching tank, filter press, and deodorizer).

2.3. Methods
The research was carried out in several steps as follows:

2.3.1. Production of cocoa butter substitute using palm kernel oil through the hydrogenation and rafination process. Process production of CBS from RBDPKO raw material was carried out based on the flow process diagram as shown in figure 1. The process mainly consisted of 3 steps: hydrogenation, rafination, and deodorizing.

The variations of treatment in this study were: nickel concentration (0.1% and 0.2%), hydrogenation temperature (170°C and 200°C), and hydrogenation duration (10, 12, and 14 hours).

The treatments for rafination were: the use of 2% bentonite (bleaching earth) and bleaching process temperature of 80-95°C for 45 minutes. The bleaching process was followed by the filtering process and the deodorization process was carried out at 240°C for 4 hours.

2.3.2. Analysis of RBDPKO and CBS. The analysis conducted included: moisture content [23], impurities [24], melting point [25], iodine number [23], free fatty acid [23], solid fat content [26], fatty acid composition [27], trans fatty acid [27] and nickel content [28].

2.3.3. Techno-economic calculation. The techno-economic calculation was conducted for evaluating the feasibility of CBS. A simple techno-economic calculation including IRR, pay-back period (PBP) and break event point (BEP).

3. Results and discussion
3.1. Raw materials analysis
An evaluation of RBDPKO quality characteristics was required before conducted CBS processing. The analysis result of RBDPKO quality characteristics is presented in table 1.

The test result was compared to the Indonesian National Standard (SNI) for Refined Bleached Deodorized Palm Kernel Oil: SNI 01-0023-1998 [29]. Based on the data presented in table 1, the raw material used met the SNI requirements.

3.2. Hydrogenation process
The main step for producing CBS from RBDPKO is the hydrogenation process. The hydrogenation process was carried out in a pressurized hydrogenation tank 100 kg/batch capacity, with a maximum stirring speed of 1700 rpm, 2.5 bar pressure, the temperature at 190-200°C, with specific processing time.

The hydrogenation equipment, designed for small and medium scale industry, consisted of a hydrogenation tank with dimensions of 40 cm diameter and 80 cm length, made of 9 mm thick SS 304 pipe material, 4000-watt heating element, 1 HP gear motor, and 1 HP inverter. The equipment accessories consisted of a manometer, pressure gauge, safety valve, thermocouple, digital thermometer, hydrogen gas cylinder, gas regulator, glass and indicator lamp, pulley, and draining valve. The hydrogenation tank was coated with SS plate, covered with glass wool, and equipped with a control panel. The design and manufacture of the hydrogenation reactor tank are shown in figure 2.

The CBS manufacturing processes commenced with the hydrogenation process. This study was conducted to find out the optimum conditions of the hydrogenation process related to factors such as nickel concentration, pressure, temperature, and time of the hydrogenation process and the optimum condition of the refining process. The raw material used was RBDPKO. The hydrogenation process was carried out using hydrogen gas and nickel catalyst (0.1% and 0.2% concentrations), at the temperature of 170-175°C and 195-200°C and hydrogenation duration (10, 12, and 14 hours) until a CBS product that met company (commercial) standards was obtained.
### Table 1. Quality characteristics of RBDPKO.

| Parameter                                      | Result | SNI Requirements |
|-----------------------------------------------|--------|------------------|
| Moisture (%)                                  | 0.07   | ≤ 0.08           |
| Impurities (%)                                | 0      | ≤ 0.08           |
| Free Fatty Acid (Oleic) (%)                   | 1.33   | ≤ 0.1            |
| Iodine Number, Wijs gram Iod/100 grams        | 14.8   | 14 - 19          |
| Trans Fat (%)                                 | 0      | --               |
| Melting Point (°C)                            | 26.5   | ≤ 30             |
| Nickel (mg/kg)                                | 0      | --               |
| Fatty Acid Composition (%):                   |        |                  |
| C₈ : 0 caprilic                               | 3.42   | --               |
| C₁₀ : 0 capric                                | 3.35   | --               |
| C₁₂ : 0 lauric                                | 48.54  | 42 - 52          |
| C₁₄ : 0 miristic                              | 15.95  | 12 - 18          |
| C₁₆ : 0 palmitic                              | 8.09   | 6 - 12           |
| C₁₈ : 0 stearic                               | 2.44   | 1 - 3.5          |
| C₁₈ : 1 oleic                                 | 15.09  | 14 - 23          |
| C₁₈ : 2 linoleic                              | 2.66   | 1 - 5            |
| C₁₈ : 3 linolenic                             | 0      | --               |

**Figure 2.** Hydrogenation equipment for the small and medium scale industry.
Based on the data collected, it could be concluded that the hydrogenation process reached its optimum conditions at the temperature of 195-200°C, the pressure of 2.5 bar, 12 hours of processing time, with 6.12 Hz stirring at 1700 rpm.

3.3. The rafination process
The hydrogenated RBDPKO produced still had an undesirable odor, a rather dark color, and potentially contained high free fatty acid and nickel residues. To overcome this problem, it was necessary to conduct the rafination process, following the hydrogenation process. The rafination process could improve color, remove odors, reduce free fatty acid, and nickel content.

Generally, the rafination process was carried out in a physical manner which included degumming, filtering, bleaching, and deodorization. Filtering was carried out to remove nickel, followed by the bleaching process in the bleaching tank. The bleaching process was conducted by adding 2% bentonite at a temperature of 80-95°C for 45 minutes. The bleaching process was followed by the filtering process using a filter press to remove bentonite and other impurities. Finally, the deodorization process was carried out using a deodorizer at 240°C for 4 hours process.

The design and manufacture of the rafination equipment in this research consisted of a bleaching tank, filter press, and deodorizer. The rafination equipment can be seen in figures 3a and 3b.

The optimum rafination process conducted consisted of filtering process by the filter press, bleaching using 2% bentonite at the temperature of 85-90°C for 45 minutes, cooling at 60°C, deodorized in a deodorizing tank at the temperature of 240°C for 4 hours and cooling at 70°C. The study showed that the rafination process conducted was able to reduce nickel content to zero, give clearer color, and remove the distinctive smell of the hydrogenation.

3.4. Analysis of product quality characteristics
The result of the analysis of RBDPKO, commercial CBS, and CBS resulted from this research can be seen in tables 2 and 3, and the solid fat content can be seen in table 4.
**Figure 3b.** The refinement equipment for small and medium scale industry (filter press).

**Table 2.** Quality characteristics of RBDPKO and CBS PKO commercial.

| Parameter                                      | RBD PKO | CBS PKO Comercial |
|------------------------------------------------|---------|-------------------|
| Moisture (%)                                   | 0.07    | 0.05              |
| Impurities (%)                                 | 0       | 0.01              |
| Free Fatty Acid (Oleic) (%)                    | 1.33    | 0.06              |
| Iodine Number, Wijs gram Iod/100 grams         | 14.8    | 1.12              |
| Trans Fat (%)                                  | 0       | < 0.005           |
| Melting Point (°C)                             | 26.5    | 36.9              |
| Nickel (mg/kg)                                 | 0       | < 0.11            |
| Fatty Acid Composition (%)                     |         |                   |
| $C_8$ : 0 caprilic                             | 3.42    | 0.98              |
| $C_{10}$ : 0 capric                            | 3.35    | 2.94              |
| $C_{12}$ : 0 lauric                            | 48.54   | 54.5              |
| $C_{14}$ : 0 miristic                          | 15.95   | 22.6              |
| $C_{16}$ : 0 palmitic                          | 8.09    | 8.30              |
| $C_{18}$ : 0 stearic                           | 2.44    | 9.95              |
| $C_{18}$ : 1 oleic                             | 15.09   | 0.13              |
| $C_{18}$ : 2 linoleic                          | 2.66    | 0.05              |
| $C_{18}$ : 3 linolenic                         | 0       | 0.08              |
The key performance indicators of the hydrogenation reaction in producing CBS could be evaluated on several factors, including a decrease in the number of iodines, an increase in melting point, changes in the content of stearic acid, oleic acid, and linoleic acid, and physical appearances such as texture, color, and aroma [22].

The twelve hours hydrogenation process could produce a CBS palm kernel oil similar to the CBS palm kernel oil commercial. The study showed that the longer hydrogenation process would produce a higher melting point. In the 10-hour hydrogenation process, it could be observed that the melting point approached the expected melting point which was around 27.9°C. The melting point reached the expected melting point at 37.1°C using a 12-hour hydrogenation process. This value is relatively close to the melting point of commercial products ranging from 34.0-34.6% as shown in Table 2.

### Table 3. Quality characteristics of CBS PKO produced from this research.

| Parameter                     | CBS PKO (10 hours process) | CBS PKO (12 hours process) | CBS PKO (14 hours process) |
|-------------------------------|-----------------------------|----------------------------|-----------------------------|
| Moisture (%)                  | 0.21                        | 0.13                       | 0.05                        |
| Impurities (%)                | 0.01                        | 0.02                       | 0.01                        |
| Free Fatty Acid (Oleic) (%)   | 0.56                        | 0.57                       | 0.06                        |
| Iodine Number, Wijs gram Iod/100 grams | 37.14                      | 0.54                       | 1.12                        |
| Trans Fat (%)                 | 8.5                         | 0                          | 2.5                         |
| Melting Point (°C)            | 27.9                        | 37.1                       | 34.0                        |
| Nickel (mg/kg)                | 0.47                        | 0                          | 0.07                        |
| Fatty Acid Composition (%)    |                             |                            |                             |
| C₈ : 0 caprylic               | 3.8                         | 3.9                        | 4.0                         |
| C₁₀ : 0 capric                | 3.2                         | 3.2                        | 3.7                         |
| C₁₂ : 0 lauric                | 48.6                        | 50.0                       | 55.9                        |
| C₁₄ : 0 miristic              | 15.9                        | 16.4                       | 18.5                        |
| C₁₆ : 0 palmitic              | 8.8                         | 12.3                       | 11.2                        |
| C₁₈ : 0 stearic               | 17.5                        | 13.0                       | 13.3                        |
| C₁₈ : 1 oleic                 | 3.4                         | 0.9                        | 0.5                         |
| C₁₈ : 2 linoleic              | -                           | 0.1                        | 0.2                         |
| C₁₈ : 3 linolenic             | -                           | 0.1                        | -                           |

Based on the test results shown in table 3, it could be concluded that for the 12 hours hydrogenation process time, the CBS Iod number decreased from its original value, 14.8 grams Iod/100 grams to 0.54 grams Iod/100 grams. This result showed that the hydrogenation process was running well. In terms of texture and color, the resulting CBS was also similar to commercial CBS.

The performance of the hydrogenation process could also be evaluated from the change in stearic acid (C 18 : 0) content. The stearic acid content in RBDPKO originally 2.44%, increased to 13.0-17.5% after the hydrogenation process. The oleic acid (C 18 : 1) content which was originally around 15.09%, reduced to 0.9-3.4%. This was caused by the process of double bond saturation. The completion of the hydrogenation process can also be seen from the change in the texture of the product, which was originally liquid RBDPKO to become semi-solid CBS RBDPKO.
Table 4. The solid fat content of CBS RBDPKO.

| Temperature (°C) | Sort of Sample (hours process) | SFC (%) |
|-----------------|-------------------------------|---------|
| 20              | 10                            | 61.24   |
| 20              | 12                            | 77.75   |
| 20              | 14                            | 76.62   |
| 30              | 10                            | 3.21    |
| 30              | 12                            | 27.51   |
| 30              | 14                            | 21.18   |
| 35              | 10                            | nd      |
| 35              | 12                            | 9.26    |
| 35              | 14                            | 5.42    |
| 40              | 10                            | nd      |
| 40              | 12                            | 0.87    |
| 40              | 14                            | 0.96    |

The value of solid fat content (SFC) of CBS is very important for the process of producing processed chocolate products. To produce good quality chocolate products, the SFC value of CBS at temperatures of 35°C and 40°C must be of low value. The results of this research show that the value of SFC produced by a 12-hours hydrogenation process time ranged from 5.42-9.46% (temperature 35°C) and ranged from 0.87-0.96% (temperature 40°C). Generally the confectionary fats (chocolate) should exhibit approximately 63% SFC at 20°C, 40% at 25°C, and 0% at 37°C [30].

3.5. Techno-economic calculation
The application of a technology or diversification of a product must be followed by a techno-economic calculation or feasibility study. The feasibility parameters used in the techno-economic evaluation of the production of CBS were an internal rate of return (IRR), pay-back period (PBP), and break event point (BEP). The techno-economic calculation was based on a discount rate of 16%. Based on the calculations, the CBS production from RBDPKO in terms of techno-economic analysis was feasible to be developed on a small and medium scale industry. The techno-economic calculation was based on the production capacity of 70 liters of RBDPKO/day. The result of the techno-economic calculation of CBS production from RBDPKO was: IRR 22.98%, PBP for 4.35 years, and BEP at Rp 116,000,000.

4. Conclusion
The optimum condition of the hydrogenation process was obtained using hydrogen with 0.2% nickel catalyst, at 195-200 °C, under 2-2.5 bar, using 6.12 hz agitation at 1700 rpm, for 12 hours process. The optimum condition of the rafination process was obtained by bleaching using 2% bentonite at 80-95°C for 45 minutes and cooling at 60°C, and deodorizing at 240°C for 4 hours. The final product of CBS had similar quality characteristics as commercial cocoa butter and as well accepted by consumers. It contained no trans fatty acid, 0 nickel, low FFA, and a melting point of 37.1°C. Based on the simple techno-economic calculation, producing CBS using RBDPKO is feasible with the value of IRR 22.98%, PBP 4.35 years, and BEP Rp 116,000,000.
Acknowledgments
Thanks to the Center for Agro-based Industry, Ministry of Industry of the Republic of Indonesia for providing research funding and laboratory facilities for conducting this research, and PT Bina Karya Prima, PPKS, and PT Tama Cokelat Indonesia for facilitating and supporting this research.

References
[1] Gunstone F 2011 Vegetable Oils in Food Technology: Composition, Properties and Uses (New York: Wiley-CRC Press) pp 291–343
[2] Biswas N, Cheow Y L, Tan C P, Kanagaratnam S and Siow L F 2017 Cocoa butter substitute (CBS) produced from palm mid-fraction/palm kernel oil/palm stearin for confectionery fillings J. AOCS 94(2) 235-45
[3] Bootello M A, Hartel R W, Garces R, Martínez-Force E and Salas JJ 2012 Evaluation of high oleic-high stearic sunflower hard stearins for cocoa butter equivalent formulation Food Chem. 134(3) 1409-17
[4] Afoakwa E O 2010 Chocolate Production and Consumption Patterns In: E O Afoakwa (ed) Chocolate science and technology (West Sussex : Wiley & Blackwell) pp 1–10
[5] Biswas N, Cheow Y L, Tan C P and Siow L F 2016 Blending of palm mid-fraction, refined bleached deodorized palm kernel oil or palm stearin for cocoa butter alternative J. AOCS 93(10) 1415-27
[6] Wei Y, Siewers V and Nielsen J 2017 Cocoa butter-like lipid production ability of non-oleaginous and oleaginous yeasts under nitrogen-limited culture conditions Appl. Microbiol. Biotechnol. 101(9) 3577-85
[7] Cisse V and Yemiscioglu F 2019 Cacao Butter and Alternatives Production Cukurova Tarım ve Gida Bilimleri Dergisi 34(1) 51-60
[8] Hassim N A M and Dian L N H M 2017 Usage of palm oil, palm kernel oil and their fractions as confectionery fats J. Oil Palm Res. 29(3) 301-10
[9] Hussain N, Agus B A P, Rahim S N F A and Halim HA 2018 Comparison of quality characteristics between compound and pure milk chocolate MOJ Food Proc. Technol. 6(3) 292-6
[10] Gibon V 2012 Palm Oil and Palm Kernel Oil Refining and Fractionation Technology. In Palm Oil (AOCS Press - Elsevier) pp 329-75
[11] Rios R V, Pessanha M D F, Almeida PFD, Viana C L and Lannes S C D S 2014 Application of fats in some food products Food Sci. and Technol. 34(1) 3-15
[12] Alsobai A M, Al Shaibani A M, Moustafa T and Derhem A 2012 Effect of hydrogenation temperature on the palm mid-fraction fatty acids composition and conversion J. of King Saud University-Eng. Sci. 24(1) 45-51
[13] Xiao H 2007 Low Trans Fatty Acid Containing Hydrogenated Edible Oils (M.D Thesis, Miami University, Oxford Ohio USA)
[14] Hariyadi P 2009 High grade specialty fats dari sawit Jurnal Info Sawit (special edition) 41-4
[15] Ramirez E, Recasens F, Fernandez M and Larrayoz M A 2004 Sunflower oil hydrogenation on Pd/C in SC propane in a continuous recycle reactor Am. Ins. Chem. Eng. 50 1-7
[16] Schmidt A and Schomaker R 2007 Partial hydrogenation of sunflower oil in a membrane reactor. J. Molec. Cat. A: Chem. 271 192–9
[17] Fernandez M B, Tonetto G M, Crapiste G H and Damiani D E 2007 Revisiting the hydrogenation of sunflower oil over a Ni-catalyst J. Food Eng. 82 199-208
[18] Murzin D Y and Simakova I L 2008 Kinetic aspect of stereoselectivity in hydrogenation of fatty acids J. Molecular Cat.: Chem. 286 156–61
[19] Kadhum A A H and Shamma M N 2017 Edible lipids modification processes: A review Crit. Rev. Food Sci. Nutr. 57(1) 48-58
[20] Stankovic M, Krstic J, Gabrovskka M, Radonjic V, Nikola D, Loncarevic, D, and Jovanovic D 2017 Supported nickel-based catalysts for partial hydrogenation of edible oils. In New
Advances in Hydrogenation Processes: Fundamentals and Applications (Croatia-In Tech)

[21] Mba O I, Dumont M J and Ngadi M 2015 Palm oil: processing, characterization and utilization in the food industry--a review Food Biosci. 10 26-41

[22] Siahaan D and Hasibuan H A 2012 Optimasi hidrogenasi minyak inti sawit skala 100 kg/batch dan rafinasi cocoa butter substitute yang dihasilkan Proc. Insinas Jakarta 37-42.

[23] Badan Standardisasi Nasional 1998 SNI 01-3555-1998: Cara Uji Minyak dan Lemak. (Jakarta-Badan Standardisasi Nasional)

[24] Badan Standardisasi Nasional 1992 SNI 01-2891-1992: Cara Uji Makanan dan Minuman. (Jakarta - Badan Standardisasi Nasional)

[25] Badan Standardisasi Nasional 2009 SNI 3748-2009: Lemak Kakao. (Jakarta - Badan Standardisasi Nasional)

[26] American Oil Chemists’ Society 1999 AOCS Official Method Cd 16b-93: Solid Fat Content (SFC) by Low-Resolution Nuclear Magnetic Resonance - The direct method 1999 (Urbana IL USA - AOCS)

[27] American Oil Chemists Society 2011 Official Methods and Recommended Practices of the American Oil Chemist’ Society 4th ed. (Champaign IL USA - AOCS)

[28] Badan Standardisasi Nasional 1998 SNI 01-2896-1998: Cara Uji Cemaran Logam dalam Makanan (Jakarta- Badan Standardisasi Nasional)

[29] Badan Standardisasi Nasional 1998 SNI 01-0023-1998: Refined Bleached Deodorized Palm Kernel Oil (RBD Palm Kernel Oil) (Jakarta- Badan Standardisasi Nasional)

[30] Biswas N, Cheow YL, Tan CP, Siow LF 2018 Physicochemical properties of enzymatically produced palm-oil-based cocoa butter substitute (CBS) with cocoa butter mixture Eur. J. Lipid Sci. Technol. 120(3) 1-9