Interesterification of Indonesian Vegetables Oil for Cocoa Butter Alternatives: Its Effect on Slip Melting Point Changes

Dianika Lestari¹2, Nathania¹, Oktalia Putri Pratama¹, and Jenny Rizkiana*²³

¹ Department of Food Engineering, Institut Teknologi Bandung, Bandung 40132 Indonesia
² Department of Bioenergy and Chemurgy Engineering, Institut Teknologi Bandung, Bandung 40132 Indonesia
³ Department of Chemical Engineering, Institut Teknologi Bandung, Bandung 40132 Indonesia

*Corresponding author: jr@che.itb.

Abstract. Palm stearin (PS), palm olein (PO), and coconut oil (CO) were used as feed for chemical interesterification to produce fat product with similar slip melting point (SMP) to cocoa butter alternatives. Chemical interesterification was conducted at 75°C for 8 hours using sodium ethoxide as catalyst. The objective of the research was to determine effect of feed composition on slip melting point profile changes during interesterification reaction. The feed composition was determined using Mixture Design method. The experimental data showed that SMP of chemical interesterification product was affected by the reactivity of the dominant fatty acid in the feed blends. The reactivity of fatty acid in the feed blend directed fatty acid positioning on the triglycerides at the end of reaction. Feed composition determined predominated portion of unsaturated fatty acids and saturated fatty acids in the mixture, and therefore, affected the gradient changes of SMP. Vegetable oil feed mixture which produced interesterification product with the most similar SMP values to cocoa butter (33-34°C) were pure coconut oil feed and palm stearin - palm olein mixture feed (50:50).

1. Introduction
Cocoa butter is vegetable fats with unique physical properties since about 80% of cocoa butter is triacylglycerols (TAGs) dominated by symmetrical TAG. The molecule is described as symmetrical TAG and often refer to as a saturated-unsaturated-saturated triglyceride SOS TAGs. The SOS TAGs are palmitic acid- oleic acid- stearic acid (POS, 36-42%), stearic acid- oleic acid- stearic acid (SOS, 23-29%), and palmitic acid- oleic acid- palmitic acid (POP, 13-19%) (Ministry of Industry, 2007). Therefore, cocoa butter has slip melting point at body temperature, 35°C (Beckett, 2008). Other than that, the cocoa butter’s production decreases cause relativity high economic value of cocoa butter. This become cocoa butter use’s problem in food industry therefore, cocoa butter alternatives (CBA) is more preferred. Various attempts have been made to find an alternative use of cocoa butter, one of them by modifying specialty fats from the cheaper fats/oil to cocoa butter alternatives. Cocoa butter alternatives can be produced by fats blending, hydrogenation reaction and interesterification reaction. Interesterification is one of the most important processes for modifying the physicochemical characteristics of oils and fat.
In Industry, chemical interesterification is the most applied interesterification modification process of oil and fats as it is simpler, cheaper, and easier to carry out compared to enzymatic interesterification (Amir, et.al., 2012). Interesterification of solid fats and vegetables oils can produce a fat blend with optimum characteristics. Interesterification product depends on feed composition and interesterification time each blend. Different blends have different triglycerides composition and slip melting point (SMP). Slip melting point is the temperature at which the column of the solid begins to rise in the tube due to buoyancy and because the outside surface of the solid is molten or solid fat content lower than 5%. Fats and oil properties characterization is determined through melting temperature parameter. The objectives of this study were to determine 1) the effect of interesterification time on slip melting point interesterification product; 2) the effect of feed composition on slip melting point interesterification product.

2. Materials and Method

2.1. Materials
Palm stearin, palm olein and coconut oil were the raw materials for chemical interesterification. Palm stearin was obtained from PT. Astra Argo Lestari Tbk. Palm olein and coconut oil were purchased from Lion Super Indo. The raw materials were stored at room temperature. Sodium ethoxide was purchased from Sigma Aldrich.

2.2. Blend Preparation
Fat blends, formulated with palm stearin, palm olein and coconut oil were mixed at different ratios. Based on mixture design- second degree lattice, simplex lattice design, fat blends were prepared as indicated in Table 1.

| Blends | Mass Compositions (w/w %) of 100 grams feed |
|--------|--------------------------------------------|
|        | Palm Stearin (PS) | Palm Olein (PO) | Coconut Oil (CO) |
| 1      | 0              | 100            | 0               |
| 2      | 50             | 0              | 50              |
| 3      | 16.67          | 66.67          | 16.67           |
| 4      | 33.33          | 33.33          | 33.33           |
| 5      | 0              | 0              | 100             |
| 6      | 66.67          | 16.67          | 16.67           |
| 7      | 100            | 0              | 0               |
| 8      | 50             | 50             | 0               |
| 9      | 0              | 50             | 50              |
| 10     | 16.67          | 16.67          | 66.67           |

Figure 1. simplex design plot.
2.3. Water content
The water content of raw material could be determined by heating the sample. Several grams sample was placed in porcelain cup which it was mass known. Then, the sample was dried for 3 hours at 105°C. After that, the sample were cooled in desiccator for 15 minutes and mass was pondered by analytical balance. Water content could be determined using equation below.

\[
\text{content} = \frac{W_2 - W_1}{W} \times 100\%
\]

where: W2: The wight of porcelain and sample before dried (g), W1: The wight of porcelain and sample after dried (g), W: the sample’s weight (g)

2.4. Batch Chemical Interesterification
The chemical reaction was started by the addition of 0.4% w/w sodium ethoxide (Sigma Aldrich) as the catalyst into fat blends prepared before according to table 1. Chemical interesterification was conducted at 75°C using sodium ethoxide as catalyst. The chemical interesterification was carried out in laboratory-scale batch reactor with agitator. The sample was agitated with average speed 300-400 rpm for 8 hours. To terminate the reaction, 20 mL 20% (w/w) citric acid solution was added. By water addition, it would non-activate catalyst by changing it into ethanol (Sreenivasan, 1978). Citric acid would react with sodium into sodium salt. Interesterification fat blends was dried again to reduce water content of sample.

2.5. Slip Melting Point
The slip melting point of the interesterified blends was determined according to the AOCS Method No. Cc 3-25 and slip melting point digital. A capillary tube filled with 1 cm high column of sample was chilled at 4 ± 1°C for 16 hours before being immersed in a beaker with cold water. The water was stirred and heated slowly. The temperature was recorded when the blend in the tube started to rise due to hydrostatic pressure. The temperature at the point was taken as the SMP.

2.6. Iodine value
The iodine number was determined by the volumetric titration method. This method referred to AOCS (1998). Iodine numbers are expressed as grams of iodine absorbed per 100gram sample. The samples were melted at 60-70°C and stirred until smooth. A sample of 0.13-0.15gram was put into the erlenmeyer and then added with chloroform p.a. 25 ml and 25 ml wijs solution, then covered and stirred until homogeneous. The mixture was putted down in a dark room for an hour. After that, the mixture was added with 20ml KI 10% and 150mL aqua dm. The solution was mixed and titrated with 0.1N thiosulfate solution until a purple-purplish colour changes exactly disappear. Next, 10% 2 mL starch indicator is added. The iodine number can be calculated as follows.

\[
\text{Iodine Value (g iod /100 g sample)} = \frac{12.69 \times N \times (V_2 - V_1)}{W}
\]

where:
N is the normality of thiosulphuric acid, V2 volume of thiosulfate used in blank determination (mL), V1 volume of thiosulfate used in sample determination, W is the test weight (gram). The following is a workflow diagram for analysis of fat iodine numbers.

2.7. Experimental Design and Statistical Analysis
Statistical analysis was done using Response Surface Methodology (RSM) and ANOVA. Type of RSM that used was Mixture Design method, simplex lattice design. Experimental results for SMP were applied to obtain the regression models, as a function of the proportions of each ingredient (x1 = palm stearin, x2 = palm olein and x3 =coconut oil) present in blends: SMP (°C) = β1X1 + β2X2 +β3X3 + β12X1X2 + β13X1X3 + β23X2X3 + β123X1X2X3, where SMP was estimated response, β was coefficient estimated by least-squares method, x was a dependent variable. The quality of models was evaluated by ANOVA and adjusted coefficient of determination (r²). ANOVA that used was Uni-variate Multi Way Analysis of Variance using Microsoft Excel.
3. Results and Discussion

3.1. Moisture Content
Moisture content is one of many parameter that indicates raw material quality due to chemical interesterification reaction. Materials that used in this research were palm stearin, palm olein and coconut oil. Moisture content analysis is used to ensure catalyst does not deactivated during reaction, therefore chemical interesterification can occur effectively. Water content describes how much water in the material but does not describe biological activity. The high moisture content in oil can make oil to demage more quickly. That is because water is hydrolysis accelerator that will produce ALB (Raharja & Gunandi, 2000). In general, chemical interesterification requires water content 0.04-11% (w/w). But, water content in chemical interesterification using sodium ethoxide catalyst will be optimum with water content lower than 0.01% (w/w). The low water content is required to support the performance of the catalyst that can be deactivated due to water content (Journal Interesterification of Oil and Fats- A Review, 2012). The water content of PS, PO and CO are shown in Table 2.

| Parameter               | Palm Stearin    | Palm Olein       | Coconut Oil     |
|-------------------------|-----------------|------------------|-----------------|
| Water content           | 0.0143% ± 0.0035| 0.0179% ± 0.0045 | 0.0006% ± 0.00015 |

According to the Table 2, palm stearin and palm olein have higher moisture content, so they are necessary for drying process as pre-treatment, but coconut oil not.

3.2. Effect of Chemical Interesterification Reaction Time on Slip Melting Point (SMP)
Cocoa butter alternatives can be produced from fat/oil blends, such as palm stearin, palm olein and coconut oil through chemical interesterification. This process was conducted for 8 hours due to overall equilibrium reaction is reached before 8 hours. The sample of interesterification product was taken every hour, then slip melting point was analyzed to evaluate physical properties changes as effect of interesterification reaction. Slip melting point changes indicates triglycerides composition/configuration changes. To determine effect of reaction time on significance of re-arrangement of fatty acids on TAG, observation of slip melting point changes was done from before reaction to 8 hours reaction. SMP at 8 hours are indicator of fat structure changes massively due to fatty acid re-arrangement to new form of triglycerides.
Figure 1. Slip melting point profile changes each product interesterification throughout reaction time on Palm Stearin (PS), Palm Olein (PO), dan Coconut oil (CO) for (a) pure feed, (b) binary blends, and (c) ternary blends.

Figure 2 showed that each variation of feed blends has different characteristic and produce a pattern of slip melting point changes during the reaction. The difference between melting point patterns are caused by fatty acids proportion in feed and also caused by the formation of new TAG with varying slip melting point, such as oleic-oleic-oleic (OOO) with SMP 5.5°C, palmitic-oleic-palmitic (POP) with SMP 37°C, and palmitic-palmitic-palmitic (PPP) with SMP 66°C. Triglycerides configuration changes due to fatty acid rearrangement on any positions of the TAG molecules during reaction, will change SMP of interesterification product. During interesterification, fatty acids (FAs) are exchanged within (interesterification) and among (interesterification triacylglycerols (TAGs)) until a thermodynamic equilibrium is reached. The other hand, interaction between the TAG molecules in mixture and rearrangement TAG for 8 hours will affect fat’s polymorphism structure that formed (Hernqvist, 1984). Polymorphism changes affects melting properties and fat crystallization behavior. This structure is specific and variative depending on TAG which make interaction. Melting temperature changes of interesterification product through interesterification indicate structure polymorphism changes. So, it can be concluded SMP product’s changes throughout reaction time indicate how massive the fatty acids exchange in feed to form new TAG.

3.3. Effect of Feed Composition of Chemical Interesterification on Slip Melting Point (SMP)

Feed composition of chemical interesterification affected slip melting point. As mentioned before, different composition will produce different characteristics. As observed in Figure 2, PS had highest SMP (48°C) fit with Teng Kim-Tiu (2014) (40-46°C), followed by CO (24°C) and PO (8°C) which fit with Siew (2002) (8-25°C). The highest fat’s SMP, the longer chain saturated fatty acid it is. According to the figure 2, slip melting point changes in many variations is classified based on slope of SMP changes throughout reaction time into 3 main pattern, scilicet insignificant pattern, pattern increased significantly, pattern decreased significantly. Insignificant pattern means the patterns are insignificant random changing. Insignificant pattern was obtained with slope lower than ± 0.5, pattern increased significantly was obtained with gradient higher than +0.5, and pattern decreased significantly was obtained with gradient higher than -0.5.

### Table 3 Comparison of initial and final SMP products of various composition.

| Feed Composition (%-w) | SMP of Feed (°C) | SMP of Product (°C) | Slope (°C/hour) | Category               |
|------------------------|------------------|---------------------|-----------------|------------------------|
| Pure Blends            |                  |                     |                 |                        |
| Pure PO                | 8                | 10                  | 0.27            | Insignificant (≤ ±0.5) |
| Pure CO                | 24               | 33                  | 1.25            | Increased significantly (> +0.5) |
| Pure PS                | 48               | 43                  | -0.72           | Decreased significantly (> -0.5) |
| Binary Blends          |                  |                     |                 |                        |
| PS:PO = 50:50          | 43               | 34                  | -0.98           | Decreased significantly (> +0.5) |
Insufficient pattern can be observed in variation of pure palm olein (PO 100), PS:CO (50:50), PO:CO (50:50), and PS:PO:CO (16.67:16.67:66.67). Overall, Insufficient pattern on SMP changes can occur due to non-identical fatty acids or the phenomena of the exchange of identical fatty acids (Mat Dian, 2007). These phenomena can occur due to feed contains a high proportion of saturated fatty acids but not balanced with the proportion of unsaturated fatty acids sufficient to trigger a massive exchange reaction. Other conditions, the phenomena are also caused by a high proportion of reactive fatty acids that cause the exchange of identical fatty acids, such as oleic acid which is quite reactive exchanging with each other because when the reaction is triggered, and oleic acid becomes free ions that produce empty spaces in the triglyceride branches so that eventually oleic free fatty acids occupy these empty branches again (Mat Dian, 2007).

![Figure 2 Illustration of rearrangement TAGs Phenomena.](image)

Pattern increased significantly can be observed in variation of pure coconut oil (CO 100), PS:PO:CO (16.67:66.67:16.67), and PS:PO (33.33:33.33:33.33). Pattern increased significantly in SMP changes can occur due to fatty acids exchange within (interesterification) and among (interesterification triacylglycerols (TAGs)) into di/tri-saturated triglycerides which have higher SMP values (Fitri.et al, 2009). The saturated TAG configuration is caused by the tendency of reactive unsaturated fatty acids to leave the triglyceride branch of full-unsaturated and attack stable saturated fatty acids (not reactive), so saturated fatty acids which is released will occupy the empty position which is left by reactive fatty acids and form triglycerides monounsaturated or monosaturated, illustration of the phenomena can be observed in Figure 3 (Fitri.et al, 2009). This reactivity phenomena can also occur in short chain fatty acids (reactive fatty acids) which are widely available in coconut oil, that every reactive fatty acid tries to find a stable position therefore make a new form (Soekopitojo, 2011 & Ratnayake, 2009). Stable branches are generally composed of long-chain saturated fatty acids.

The third pattern of melting point changes is the pattern decreased significantly which can observed in variations of pure palm stearin (PS 100), PS:PO (50:50), and feed PS:PO:CO (66.67:16.67:66.67). These phenomena occurred due to the exchange of fatty acid chains on triglycerides from saturated TAG into mono-saturated TAG (Fitri.et al, 2009). In all variations of blends, the feed is dominated by full-saturated triglycerides (PPP) and saturated TAGs such as POLa / POS / POP which are classified as monounsaturated TAGs as products so that patterns of temperature changes occur. Monounsaturated

| Ternary Blends | PO:CO = 50:50 | 22 | 21 | -0.21 | Insufficient (< +0.5) |
|----------------|---------------|----|----|-------|---------------------|
| PS:CO = 50:50  |               | 26 | 30 | 0.3   | Insufficient (< +0.5) |
| PS:PO:CO = 33.33:33.33:33.33 | 32 | 40 | 0.87 | Increased significantly (> +0.5) |
| PS:PO:CO = 66.67:66.67:16.67 | 31 | 37 | 1.25 | Increased significantly (> +0.5) |
| PS:PO:CO = 16.67:66.67:16.67 | 8  | 18 | 1.05 | Increased significantly (> +0.5) |
| PS:PO:CO = 16.67:16.67:66.67 | 25 | 29 | 0.50 | Insufficient (> +0.5) |
Triglycerides have lower melting temperatures than saturated TAGs. Thus, the mixture has a decreased melting point due to a decrease in the concentration of saturated triglycerides in the mixture which is replaced by an increase in the number of unsaturated TAGs (Ratnayake, 2009).

As mentioned before, different proportion of feed will produce different characteristic, specifically in slip melting point and iodine value due to proportion of fatty acids in feed to form new TAGs. Slip melting point analysis in Figure 2 indicate that SMP changes during reaction depending on compositions and configuration of fatty acids on TAG. The compositions and configurations are produced from three types of fatty acids with different ratio. Therefore, the different proportions of each fatty acids in each feed composition affects SMP value of interesterification product, so comparison of SMP value for each variation needs to be done. The comparison is done on interesterification product for 8 hours. The data was taken at 8 hours due to overall, equilibrium reaction is reached before 8 hours. To determine effect of proportion of fatty acids in SMP, iodine value is observed to identify the proportion of saturated fatty acids in each feed.

![Figure 3](image1.png)

**Figure 3** contour plot and SMP response plot of the 8th hour interesterification product from various fat blends.

Each raw material has a different response, in this case slip melting point as a response. Statistical analysis using Response Surface Method (RSM) show that the addition proportion of palm stearin in the mixture, it will increase SMP, while the reduction proportion of palm stearin in the mixture, it will give an antagonist effect; the addition proportion of palm olein in the mixture, it will decrease SMP exponentially, while the reduction proportion of palm olein in the mixture, it will increased SMP; the addition proportion of coconut oil in the mixture, it will decrease SMP exponentially, while the reduction proportion of palm olein in the mixture, it will increased SMP. Illustration is shown in Figure 4. Then, effect of feed composition on iodine value is determined due to link the correlation with the effect of PS, PO, CO on iodine value. It can be concluded that palm stearin works antagonistic with palm olein and coconut oil.

![Figure 4](image2.png)

**Figure 4** contour plot and IV response plot of the 8th hour
interesterification product from various fat blends

According to Figure 5, the addition proportion of palm stearin and coconut oil in the mixture, it will decrease iodine value, while the addition of palm olein in the mixture, it will increased iodine value. illustration is shown in Figure 5. It can be concluded that palm stearin and coconut oil work antagonistic with palm olein.

This phenomena is clarified by observing nature fat characteristic. Palm stearin is dominated by long chain saturated fatty acids, palm olein is dominated by long unsaturated fatty acids, and coconut oil is dominated by medium chain saturated fatty acids. The addition of fatty acids in TAGs form in the mixture will change the fatty acids proportions and affect on slip melting point, polimorfism and solid fat content. The fatty acids proportions is indicated through iodine value of mixture.

![Figure 5](image)

**Figure 5** Effect of medium chain saturated FAs, long chain saturated FAs, and long chain unsaturated FAs composition on iodine value.

Based on Figure 6, the correlation between fatty acids and iodine value match with Silvia Oliver (2019) that unsaturated fatty acids and iodine value have linear correlation. Fatty acids also affect slip melting point blends. Figure 7 illustrates mixture contour plot of temperature.

![Figure 6](image)

**Figure 6** plot contour of the distribution of slip melting point values in various proportions of fatty acids.
Figure 7 shows that unsaturated fatty acids have the effect of producing fat with a low melting temperature which is below 10°C at high concentrations and below 30°C at low concentrations. While medium chain saturated chain fatty acids can produce fat at medium temperatures in the range 30-40°C at high concentrations. In long-chain saturated fatty acids, the resulting melting temperature can reach more than 60°C at high concentrations. Observation of the value of iodine number and melting temperature (SMP) can form an interconnected pattern where the melting temperature value in general will be inversely proportional to the value of iodine number. High melting temperatures will be obtained from saturated fatty acids which have low IV, while low melting temperatures will be obtained from unsaturated fatty acids which have high IV. However, the values obtained cannot be connected in a linear line or a simple polynomial equation.

$$T ( ^{0}C) = -3.1 \times 10^{-5} IV^4 + 3.36 \times 10^{-4} IV^3 - 0.145 IV^2 + 3.39$$ \hspace{1cm} (3)

Figure 7. The correlation between slip melting point and iodine value.

Based on the equation of the correlation between IV and SMP, it can be indicated that the iodine value varies in melting temperature values. The variation in temperature values is based on the range of iodine values. This range of variation causes the relationship between iodine value and SMP not to cause a constant rise. Figure 8 shows that the range of variations in the iodine value (abscissa axis) value with the slip melting point (ordinate axis) is divided into 3 parts, iodine range 0-12 which is the identity of fat with the predominance of saturated fatty acids, range 12-40 which is an identity for fat with a predominance of saturated fatty acids, and a range of 40-63 which is an identity for fats with a predominance of unsaturated fatty acids.

4. Conclusions

The interesterification reaction successfully changes the slip melting point value throughout the reaction time with insignificant pattern, the increased significantly pattern and the decreased significantly pattern. The insignificant pattern occurred on variations of pure palm olein, PS:CO (50:50), PO:CO (50:50), and PS: PO: CO (16.67: 16.67: 66.67), the increased significantly pattern occurred in variations of pure coconut oil, PS: PO: CO (16.67: 66.67: 16.67), PS: PO: CO (33.33: 33.33: 33.33 ), the decreased significantly pattern occurred in pure palm stearin, and PS: PO (50:50), PS: PO: CO (66.67: 16.67: 16.67).

Variation of composition of fat mixture determines the portion of unsaturated fatty acids and saturated fatty acids. The portion of fatty acids in the mixture caused variations in the feed’s and product’s slip melting point and the iodine value. Feed composition which produced 33-36°C as slip melting point are PS: PO (50:50)-34°C and CO (100)-33°C.

Iodine value changes is directly proportional to the addition of saturated fatty acids and /or unsaturated fatty acids in the mixture. The more percentage of unsaturated fatty acids in the mixture, the higher the value obtained.
Acknowledgments
This research was funded by P3MI Research Grant provided by Institut Teknologi Bandung.

References
[1] Berry S E E 2014 Rich fats : An overview and implications for cardiovascular disease Triacylglycerol structure and interesterification of palmitic and stearic acid-rich fats : an overview and implications for cardiovascular disease (London: King’s College London)
[2] Chapman D 1962 The Polymorphism of Glycerides Chemical Reviews 62 (5) 433-456.
[3] da Silva Oliveira et all 2019 Mature chemical analysis methods for food chemical properties evaluation. In Evaluation Technologies for Food Quality (pp. 63-90). Woodhead Publishing.
[4] Dian N L H M et all 2007 Effect of chemical interesterification on triacylglycerol and solid fat contents of palm stearin, sunflower oil and palm kernel olein blends European Journal of Lipid Science and Technology 109 (2) 147-156
[5] Hernqvist L and Herslöf M 1984 Polymorphism of interesterified triglycerides and triglyceride mixtures Fette, Seifen, Anstrichmittel 86 (10) 393-397
[6] Hazirah S 2012 Effects of Chemical Interesterification On The Physicochemical Properties Of Palm Stearin, Palm Kernel Oil And Soybean Oil Blends. (Malaysia: Universiti Teknologi MARA.16(3), 297–308.
[7] Karupaiah T & Sundram K 2007 Effects of stereospecific positioning of fatty acids in triacylglycerol structures in native and randomized fats: a review of their nutritional implications Nutrition & metabolism 4 (1) 16
[8] Kumar P K P & Krishna A G G 2015 Physicochemical characteristics of commercial coconut oils produced in India Grasas y Aceites 66 (1)
[9] Neff et all 2001 Triacylglycerol structures of food fats high in saturated acids by HPLC and mass spectrometry (Journal of liquid chromatography & related technologies (USA: Food Quality and Safety Research, NCAUR, ARS, USDA) 24 (6) 837-854
[10] Omar K A et all 2017 Triacylglycerol composition, melting and crystallization profiles of lipase catalyzed anhydrous milk fats hydrolyzed International journal of food properties (Jiangsu: Jiangnan University) 20(sup2) 1230-1245
[11] Palm I E (n.d.) Oil Palm: Fractions & Derivatives Palm Oil process Oil Palm : Fractions & Derivatives Palm Kernel Oil process
[12] Karabulut I 2003 Effects of chemical interesterification on solid fat content and slip melting point of fat / oil blends Turkey Hacettepe University 224–229
[13] Soares D M et al. 2012 Chemical Interesterification of Blends of Palm Stearin, Coconut Oil, and Canola Oil: Physicochemical Properties. (Brazil: Sao Paulo)
[14] Soekopitojo S 2012 Asidolisis enzimatik fraksi tengah minyak sawit dengan asam stearat untuk sintesis cocoa butter equivalents (Bogor: Institut Teknologi Bogor) 34 (2)