Fatty Acid Direct Production from Palm Kernel Oil

R Tambun, D G Ferani, A Afrina, J A A Tambun, I A A Tarigan
Department of Chemical Engineering, Universitas Sumatera Utara, Padang Bulan, Medan 20155, Indonesia
Email: rondang@usu.ac.id

Abstract. Fatty acid is one of oleochemical products that can be obtained from palm kernel oil. The fatty acids can be produced enzymatically hydrolyzing palm oil by using lipase. This study aims to assess the conversion of palm kernel oil into fatty acids with activate lipase enzyme in palm kernel. Observation of this research consist of variety of duration of hydrolysis, the hydrolysis reaction temperature, and the addition of water. The highest percentage of fatty acid produced in this research is 34.645 %. This result obtained at 2 hours of hydrolysis reaction time and 40% of water addition at 35 °C, and the fatty acid produced in this study is dominated by lauric acid with a composition of 52.465%.

1. Introduction

The palm kernel oil (PKO) products are abundant in Indonesia. This PKO is very potential to be processed into oleochemical materials. Oleochemical is a chemical derived from natural fats, both plants and animals [1]. At this time and in the future, oleochemical products are expected to play a larger role in replacing petroleum derivative products (petrochemicals). This is understandable because oleochemical products have several advantages over petrochemical products, such as prices, renewable sources and eco-friendly products. Until now, the oleochemical industry is still based on triglycerides as their raw materials. It is still very rare to find an industry that processes raw materials directly into chemicals without going through triglycerides. Though economically and technically, many products from natural materials that can be processed directly from vegetable materials without going through triglycerides.

One of the oleochemical products that can be treated without going through triglycerides is the fatty acid of the oil palm fruit. Figure 1 shows the steps of making fatty acids. During this time, the palm fruit is processed into crude palm oil (CPO) and PKO, then CPO and PKO is refined to be refined bleached deodorized palm oil (RBDPO) and refined bleached deodorized palm kernel oil (RBDPKO). RBDPO or RBDPKO is then hydrolyzed into fatty acids. This way need three steps to product fatty acid from palm fruit oil.

Currently, the process of making fatty acids is carried out by hydrolysis process at a temperature of about 240 °C - 260 °C and a pressure of 45 bar - 50 bar, and can also by enzymatic hydrolysis process using lipase enzyme. Both of these processes are considered uneconomical because of their large energy consumption, as well as the price of expensive enzymes resulting in high production costs. To overcome this problem, an effort is needed to reduce the cost of producing fatty acids by activating the lipase enzyme contained in the palm fruit, both mesocarp and PKO [2-3]. The fatty acid can be producted directly from palm oil fruit by activating the lipase enzyme contained in the palm fruit, so this way can reduce the cost of fatty acid production.

This research will be investigated the making of fatty acid directly from PKO, that is by activating the lipase enzyme contained in the palm kernel. Tambun R (2007) has hydrolyzed the palm fruit directly by activating lipase enzyme in the fruit of palm (mesocarp), where in the research can be reached the fatty acid content up to 56% [4].

PKO has a saturation level of 81% with the largest content is lauric acid. One of the oleochemical products that can be obtained from PKO is fatty acids. These fatty acids are widely used in various industries such as tire industry, cosmetics, plastics, paints, pharmaceuticals, detergents and soaps. In addition, fatty acids are used as raw materials for the production of oleochemicals such as fatty alcohols, fatty amines and fatty esters [1,3].
Figure 1. Fatty acid production process from palm oil fruit.

Palm and palm kernels that have been harvested contain lipase enzymes that keep working in the fruit before the enzyme is stopped. Lipase enzyme acts as a catalyst in the formation of fatty acids. Lipase enzyme capable of hydrolyzing fat or oil to produce free fatty acids. Fats in seeds or fruit will be enzymatically hydrolyzed with the help of lipase enzymes to break them down into fatty acids [5-7].

In oil palm, oil begins to accumulate on unripe fruit and its development will be very fast about 130 days after pollination. In oil palm bunches, the fruit will not mature simultaneously. In one bunch, there are unripe, ripe and very ripe fruits. Standard minimum maturity of fruit is usually done if one of the fruits has been removed by itself from the bunch before harvesting. This means that when one of the fruits has been removed from the bunches, the other fruit still in the tree / bunch will mature. To overcome this problem, the harvest interval between 7 and 10 days is done depending on the age and type of oil palm.

The oil content in fruit depends on the maturity of the fruit, where the oil content in the fruit will be maximized if the fruit is completely ripe, and the oil content will be low if the fruit is not yet ripe [6]. The development of fatty acids in palm oil is influenced by lipoids contained in oil and the ability of autocatalytic hydrolysis spontaneously by lipase enzyme [6]. Figure 2 shows the steps of triglyceride hydrolysis process by lipase enzyme to produce free fatty acid (FFA).

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\begin{align*}
\text{Triglyceride} + \text{Water} & \underset{\text{lipase}}{\rightleftharpoons} \text{Diglyceride} + \text{FFA} \\
\text{Diglyceride} + \text{Water} & \underset{\text{lipase}}{\rightleftharpoons} \text{Monoglyceride} + \text{FFA} \\
\text{Monoglyceride} + \text{Water} & \underset{\text{lipase}}{\rightleftharpoons} \text{Glycerin} + \text{FFA} \\
\text{Triglyceride} + 3 \text{Water} & \underset{\text{lipase}}{\rightleftharpoons} \text{Glycerin} + \text{FFA}
\end{align*}
\]

Figure 2. Step of Triglyceride Hydrolysis by Using Lipase Enzyme.

2. Methods
The materials used in this study are palm kernel, aquadest (H\textsubscript{2}O), sodium hydroxide (NaOH), ethanol (C\textsubscript{2}H\textsubscript{5}OH) and phenolphthalein (C\textsubscript{20}H\textsubscript{14}O\textsubscript{4}), while the equipment used, among others Gas Chromatography, beaker glass, hot plate, water bath, oven, and burette. In this experiment, the palm fruit is removed from its bunch, then the fruit is peeled to separate the kernel and mesocarp. Then, the kernel of the palm is separated from the shell and then milled.

The crushed palm kernel is inserted into a beaker glass, then water is added as much as 0%, 20%, 40%, 60%, 80%, and 100% (w/w). The mixture is then stirred using a mixer at 300 rpm for 10 minutes and left for a certain length of time at 27 °C (room temperature) and 35 °C (optimum temperature of lipase enzyme). After that, the sample is dried by using oven at 105 °C for 1 hour to stop the activity
of lipase enzyme. Then the fatty acid content in oil is analyzed. Fatty acid content is analyzed by titration based on AOCS Official Method Ca 5a-40, and fatty acid composition is analyzed by gas chromatography method [8].

3. Results and Discussion

3.1 Effect of hydrolysis reaction time on fatty acid content of PKO

Figure 3 shows that the reaction time has a significant effect on the fatty acid content of PKO. In this figure, we can see that at a temperature of 27 °C the graph increases up to 6 of reaction time hours and then decreases over a period of 24 hours, and at temperature of 35 °C, the graph increases up to 2 hours of reaction time and then the graph decreases over a period of 24 hours. According to Li D, et al., (2015), the hydrolysis reaction of triglycerides is a reversible reaction [7]. Hydrolysis up to a certain length of time will increase lipase activity, but if hydrolysis is continued, the lipase activity will decrease which will decrease its hydrolysis product [2, 4, 6]. The decline of hydrolysis products in the form of fatty acids is suspected because at a certain concentration the presence of fatty acid actually inhibits the next hydrolysis reaction. Another cause of the decline in fatty acids is because the fatty acids have achieved maximum results for a long hydrolysis of 2 hours, and if the hydrolysis is continued again, the fatty acid will be decomposed again into reactants. Figure 3 shows that the highest yield of 34.645% at temperature of 35 °C is obtained when the reaction time of 2 hours, while at temperature of 27 °C, the highest yield of 23.389% is obtained when the reaction time of 6 hours. When the reaction time of 6 hours and the reaction temperature of 35 °C, the fatty acids decrease to be 32.538%.

![Figure 3. Influence of Reaction Time to Fatty Acid Content of PKO when Water Addition of 40%](image)

3.2 Effect of water addition on fatty acid content of PKO

Figure 4 shows that at a temperature of 27 °C, there is an increase in fatty acid content up to 60% water addition, then the fatty acid content decreases up to 100% water addition, while at a temperature of 35 °C there is an increase in fatty acid content up to 40% water addition, then the fatty acid content decreases up to 100% water addition. Water content is one of the most important parameters to investigate, especially in the enzymatic reaction of organic media. Water reacts as a reactant in hydrolysis reaction and a as modifier for lipase function during reaction. The amount of water present
in the system will affect the reversibility of the reaction either to hydrolysis or esterification directions. Increased water content promotes balance in a positive reaction, which increases the degree of hydrolysis so that the reaction will produce high contents of fatty acids [8-10]. Based on the results of the study, the water content required in the hydrolysis process to produce maximum fatty acid content is 40% (w/w) at 35 °C. At low water content (below 40%), hydrolysis reaction is incomplete. This is because the lipase enzyme also catalyzes the simultaneous esterification reaction that coincides. So this reaction must require large amounts of water to convert the equilibrium into hydrolysis [5]. However, when hydrolysis is carried out in a mixture that has excess water content, the degree of hydrolysis will decrease. This happens because if the water content is too high, the hydrolysis rate will slow down because of the decrease of contact between the lipase and the oil. Excess water will create a thick layer of water around the surface of the enzyme and cause diffusivity problems of substrates and products from the active site of the enzyme. Excess of water content in the reaction will also cause the denaturation of the protein content of the enzyme permanently [10].

![Figure 4](image-url)

**Figure 4.** Influence of Water Concentration to Fatty Acid Content of PKO for 2 Hours of Reaction Time.

### 3.3 Fatty Acid Composition Analysis

Based on gas chromatography analysis, fatty acid composition (w/w) of PKO is as shown in table 1. According to fatty acid composition of PKO, the molecular weight of PKO fatty acid is 211.392 g/mole. Based on gas chromatography analysis, the highest saturated fatty acid component is lauric acid of 52.465% (w/w), and the highest unsaturated fatty acid component is oleic acid of 11.284% (w/w), while according to Corley and Tinker (2015), PKO contain of lauric acid of 46%-52%, myristic acid of 14%-17%, and oleic acid of 13%-19% [11].
Table 1. Fatty Acid Composition of PKO.

| No. | Components               | Composition (%) |
|-----|--------------------------|-----------------|
| 1   | Caproic acid (C₆:0)      | 0.298           |
| 2   | Caprylic acid (C₈:0)     | 4.683           |
| 3   | Capric acid (C₁₀:0)      | 4.281           |
| 4   | Lauric Acid (C₁₂:0)      | 52.465          |
| 5   | Myristic acid (C₁₄:0)    | 15.645          |
| 6   | Palmitic Acid (C₁₆:0)    | 7.536           |
| 7   | Stearic Acid (C₁₈:0)     | 2.098           |
| 8   | Oleic Acid (C₁₈:1)       | 11.284          |
| 9   | Linoleic Acid (C₁₈:2)    | 1.545           |
| 10  | Arachidic Acid (C₂₀:0)   | 0.097           |
| 11  | Eikosenoic acid (C₂₀:1)  | 0.068           |

4. Conclusion

Fatty acids could be produced by hydrolyzing palm kernel oil by activating the lipase enzyme contained in the palm kernel. The highest fatty acid content of 34.645% is obtained at 2 hours of hydrolysis reaction time and 40% of water addition at 35 °C. The fatty acid produced in this study is dominated by lauric acid with a composition of 52.465%.

5. References

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