

The Production of Biofuels from Coconut Oil Using Microwave

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Abstract

Biofuels including biodiesel, an alternative fuel, is renewable, environmentally friendly, non-toxic and low emission energy. The raw material used in this work was coconut oil, which contained saturated fatty acids about 90% with medium chain (C₈-C₁₂), especially lauric acid and myristic acid. Reaction was conducted in batch reactor assisted by microwave. The purpose of this research was to study the effect of power and NaOH catalyst in transesterification enhanced by microwave and to obtain a biofuels (biodiesel and biokerosene) derived from coconut oil. The reaction was performed by mixing oil and methanol with mole ratio of 1:6, catalyst concentration of 1% w/w with setting electrical power at 100, 264, 400, 600 and 800 W. The reaction time was conditioned at of 2.5, 5, 7.5, 10 and 15 min. The results showed that microwave could accelerate the transesterification process to produce biodiesel using NaOH catalyst. The highest yield of biodiesel was 97.76 %, or 99.05 % conversion at 5 min reaction, meanwhile biokerosene was 48% after distillation.

Keyword: transesterification, biodiesel, biokerosene, coconut oil, microwave

1. Introduction

The use of petroleum still dominates the energy consumption in Indonesia, especially in the transport sector. Utilization of fuel in the transport sector in this country from 2003 to 2025 predicted will be increasing an average 6% per year. Indonesia has turned from a net exporter to a net importer of oil in recent years. It faces heavy challenges since the price of petroleum increases continually. Subsidized policy on petroleum fuel implemented for decades has been burdensome of government budget. The high price is inevitable to set on international price but it will greatly affect the poor people. To overcome energy scarcity, the government launched a regulation for developing of alternative energy stipulated in Presidential Instruction No. 25 year 2006 and Government Regulation No. 5 year 2006. Those policies were regulated the national energy that reinforces the development of renewable energy and substitution a part of fossil based fuels with biofuels. One of the important point of regulation is a reduction in fuel consumption from 54% to 20%. In an effort to overcome the deficit of fuel, especially diesel oil and kerosene, the development of alternative fuels as an alternative energy is a strategic choice. An alternative energy is indispensable as the use of petroleum increases year by year (Handayani et al., 2012). One of the renewable sources, which can be developed to be bio-fuel, is a vegetable oil. In Indonesia, biofuels were still being developed from some renewable materials, which the sources were as follows: food oils, such as palm and coconut oil, non-edible oils - *Jatropha curcas*, neem and others (Demirbas, 2006). Biodiesel, as a renewable fuel, has some advantages compared to fossil fuels as follows: environmentally friendly, biodegradable and lower emission and made from renewable materials, consists of alkyl esters of fatty acids and it can be prepared from vegetable, animal and used cooking oil, or recycled oil (Zabeti et al., 2010).

Vegetable oils that can be developed as a raw material for manufacturing of biodiesel are obtained from palm plants, castor and calophyllum inophyllum fruit (Oliveira et al., 2013). Fatty acids are reacted with an alcohol yielded ester and glycerin (by product) via trans-esterification. Even though glycerin is by product, its price is quite high. Among alcohols is commonly used is methanol for it is cheaper and more reactive than others (Hsiao et al., 2011).

Preparation of biodiesel has been widely developed in the conventional manner. The development of biodiesel has

been applying microwave to accelerate the reaction as reviewed by authors (El Sherbiny et al., 2010., Tippayawong et al., 2012). The use of microwaves is an alternative to manufacture of biodiesel enhancing the conversion. The mechanism of heating in microwave application is radiation absorbed by polar molecules-water, sugars and fats as well as other substances. Heating takes place simultaneously and uniformly on the excited atoms and produce heat at the same time. Microwave provides many advantages as follows: fast startup time, faster heating, efficient energy and the lower process cost, easy to monitor, precise, selective heating and the better quality of product (Jiputti et al., 2006).

Coconut oils consist of various kinds of triglyceride fatty acids, which saturated fatty acid accounted 90% and are rich of medium chains (C_8 - C_{12}), especially lauric acid and myristic acid. The compositions of fatty acids are 6.21% caprylic acid, 6.15% capric acid, 51.02% lauric acid, 18.94% myristic acid, 8.62% palmitic acid, 1.94% acid stearic, 5.84% oleic acid and 1.28% linoleic acid (Chowdhury et al., 2007). Coconut oil as a raw material has advantages compared other vegetable oils, it contain 60% medium chains of fatty acids. Those are possible to obtain other fuels such as kerosene, or jet fuel. This research was aimed to study the development of the process of the preparation of biodiesel from coconut oil by utilizing the microwave as an energy source and to separate the fractions of products.

2. Materials and Methods

2.1 Materials

Coconut oil used was the refinery commercial (Barco. Co) from Indonesia. The commercial methanol (in purity 96 %) was purchased from Brataco. Co. Ltd. (Indonesia) and NaOH, p.a MERCK, (in purity: 99 %) was obtained from a local chemical supplier (O.V. Chemicals, Co. Ltd).

2.2 Equipment

The microwave as source energy was performed to produce biodiesel conducted in a batch reactor. The design of equipment used in this study is shown in Figure 1. The reactor was a flat bottom flask made from Pyrex glass equipped with magnetic stirrer. The microwave oven used was Electrolux Microwave EMM2007X with a frequency of 2.45 GHz, power output from 0 to 800 Watts and 0 to 30 min time setting. To separate fractions of biofuels employed heating mantle, a three neck flask, condenser and vacuum pump.

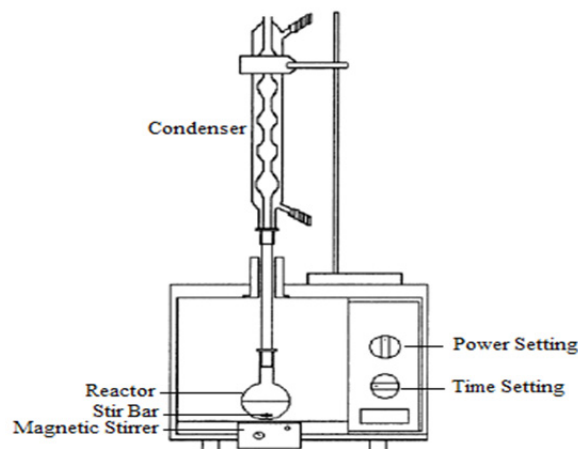


Figure 1. The experiment setup for transesterification process assisted by microwave

2.3 Experimental Procedure

2.3.1 Analysis of FFA Content

Two grams of oil was added into 25 ml 98% ethanol inside Erlenmeyer flask by stirring. Three drops of phenolphthalein indicator were added into solution and titrated with KOH 0.1 N, which was done until the color changed to pink. The KOH content was calculated by using an equation (SNI 7182 2012) as follows:

$$(\%) \text{ FFA} = \frac{\text{MW (fa)} \cdot \text{V} \cdot \text{N}}{10 \cdot \text{m Oil}} \times 100$$

Where, MW(fa) is molecular weight average of fatty acid and recorded at 226.34 g/mole); V is KOH volume needed for titration; N is normality of KOH (0.1N) and m is coconut oil weight (2 g).

2.3.2 Transesterification Using Microwave Heating

Coconut oil was introduced into the reactor and mixture of methanol and NaOH were added. The molar ratio oil to the methanol was 1:6 and alkaline catalyst used for reaction was 1%.wt. The fifty milli liter coconut oil (with 0.913 gr/ml) was fed to the reactor and mixed with 6 mole methanol per running. The solution was reacted in a 250 ml reaction flask with a set reflux tools. Microwave apparatus was modified by making hole on the top of casing to put the condenser. The reaction was started by turning on the microwave power set at 100 W and 2.5 min. The process was repeated for 264, 400, 600 and 800 W and 5, 7, 10 and 15 min. After completion, the product was kept in separating funnel for 12h for separating the methyl ester and glycerol. The methyl ester was washed using warm water for three times and the product was dried at 110 °C for 1 h. The methyl ester obtained was proceeded by vacuum distillation to separate biokerosene from biodiesel at 185°C and 70mmHg.

2.3.3 Analysis of Product

The parameters of biodiesel were analyzed as follows: viscosity (ASTM D445), specific gravity (ASTM D1298), flash point (ASTM D93) and acid number (ASTM D 664) carried out in triplicate. Biodiesel yield, defined as the weight percentage of product over to the initial weight of coconut oil. The concentrations of biodiesel were analyzed by gas chromatography (6890 GC) equipped with a capillary column Agilent 19095N-123 INNOWAX, (30 m x 0.53 mm x 1µl) and a flame ionization detector (FID) as well as Helium was the carrier. The conversion was calculated from the content of methyl ester analyzed by GC with the following equation:

$$\text{Conversion (\%)} = \frac{(W_{\text{biodiesel produced}} / MW_{\text{biodiesel}} \times C_{\text{biodiesel}})}{3(W_{\text{oil}} / MW_{\text{oil}})} \times 100$$

MW (molecular weight) of biodiesel and oil were calculated according to the composition of fatty acid shown in Table 1. The factor 3 in formula was taken for the fact that each triglyceride forming three moles of methyl ester.

3. Results and Discussion

3.1 Characterization of Coconut Oil

Table.1 describes the types and compositions of fatty acid characterized by gas chromatography. The highest contents were 41.2 % lauric acid and 23.90 % myristic acid, which were suitable to previous studies (Chowdhury et al., 2007, Eqbal et al., 2011). Prior to used, the properties of coconut oil, free fatty acid, acid number, density and viscosity, were measured as shown in Table 2. When FFA was lesser than 1 percent, the transesterification was conducted one step and bigger than 1 percent, the process was carried out 2 steps (Van Garpen et al., 2004). It was measured that the viscosity of raw material was recorded about 27.5 mm²/s as shown in Table 2.

Table 1. Fatty acid profile of feed stock

No	Name of fatty acid	Composition (wt.%)
1	Caprylic acid	0.27
2	Capric acid	3.91
3	Lauric acid	41.21
4	Myristic acid	23.90
5	Palmitic acid	16.50
6	Stearic acid	3.14
7	Oleic acid	9.47
8	Linoleic acid	1.61

Table 2. Physicochemical properties of coconut oil

Properties	Unit	Coconut Oil Barco
Water content	%	0.976
Density	g/ml	0.913
Viscosity	mm ² /s 40 °C	27.5
Free fatty acid	%	0.143
Acid number	mg.KOH/g.oil	0.392

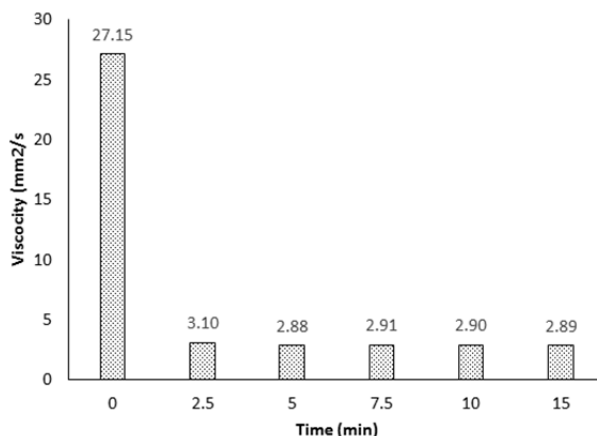


Figure 2. Effect of Reaction time on biodiesel viscosity at 1:6 molar ratio, 1% NaOH and power 100W

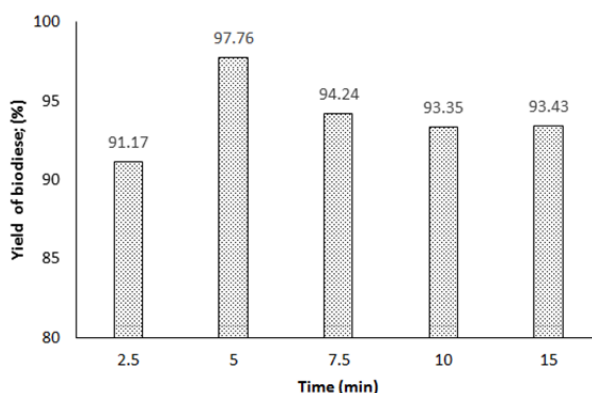


Figure 3. Effect of reaction time on biodiesel yield (1:6 molar ratio, 1.0 % NaOH, and power of 100 W)

3.2 Effect of Reaction Time toward Product Viscosity and Yield

Experiment was carried out with 1wt % NaOH for various microwave powers in which input power influenced to the amplitude of wave. The greater the power used to generate the microwaves, the bigger the electric field generated (Lidstrom et al., 2001). If the electric field rises, the amplitude of the microwave increases. The rotational speed of polar molecules have a linear relationship to the amplitude of the microwave. The amplitude inclines as polar molecules rotation increases so the heating process is accelerated.

Figure 2 shows the effect of reaction time power on the transesterification process to the viscosity of biodiesel. It was found that the viscosity extremely decreased from 27.5 to 2.3 mm²/s for 0 to 2.5 min and was relatively constant for 2.5-15 min. It was indicative that the reaction had completed in 2.5 min. It was surprising that the viscosities of products were relatively similar for all powers as shown in figure. The decrease of viscosity was due to the power directly affected the heating process as reported by authors (Gude et al., 2013).

Figure 3 shows the yield of product obtained respect to reaction time conducted at 100W. The yields of product significantly increased to 91.17% at 2.5 min and 97.76% at 5 min. After 5 min, the yields slightly decreased and then was relatively constant. This indicated that the longer time did not significantly influence the yield of biodiesel. It was characteristic of biodiesel preparation using microwave that needed less time (Chen et al., 2012).

3.3 The Effects of Microwave Power on the Yield of Biodiesel

Figure 4 describes the effect of microwave power on yield of biodiesel conducted at 1% NaOH for 5 min. and molar ratio of oil to methanol was 1: 6. Generally, the yield of biodiesel decreased as the power increased, which was similar to other works (Galema, 1997). The increase of microwave power caused the damage of organic substances, such as triglycerides (Saifuddin et al., 2004). The energy required for the microwave method was 23 times lower than that of the conventional method (Pathil et al., 2010). This case showed that the use of microwave in transesterification reaction with NaOH was better conducted within a low power 100 W. It was found that preparation biodiesel assisted microwave was conducted in short time, 5 min compared to

conventional technique taken for 1 h as previously published study (Chen et al., 2012).

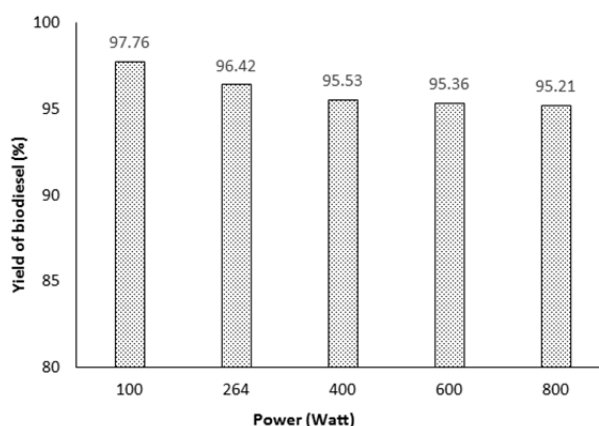


Figure 4. Effect ofmicrowaves power onbiodiesel production

The highest yield of biodiesel obtained was 97.65% at 100W for molar ratio of oil to methanol 1:6. While, the yields at 264 until 800 W decreased to 96.42% to 95.21%. The decrease of yield caused by the inclining of temperature in short time so methanol was continually evaporated and condensed, which triggered the saponification reaction. The improvement of power increased the rate of microwave beams so that excitation occurred in the molecules. The preparation conducted above 60°C using NaOH was not effective because of the rivalry between transesterification and saponification reactions as previously published by Dorado, et al, (2004). Therefore, the process of transesterification reaction using NaOH in microwaves should be carried out with shorter time, which was less than 60 min. The heating by microwaves in liquid and solids compounds occurred, where the electromagnetic energy was transferred into heat. The heating effect of microwave forced dipoles and ions to rotate from slow to fast motions.

3.4 Separation of Biodiesel and Biokerosene

The methyl ester prepared was proceeded to separation process to obtain biokerosene. The separation was conducted heating conditioned at 185°C and 70 mmHg. The heating was maintained until the distillate dropped. The amount of methyl esters separated was 100 ml and biokerosene was 47.5 ml after heating for 45 min. The biokerosene was evaporated and condensed to be distillate, meanwhile methyl ester was not escaped from bottom distiller for its boiling point was higher than that distillate. The product, which was not evaporated was golden yellow, and distillate was more transparent.

3.5 Biodiesel Properties of Coconut Biodiesel

The quality of the product is determined by several parameters, such as cetane number, kinematic viscosity, density, and others. Table 3 describes the comparisons of biodiesel properties obtained compared to those of biodiesel ISO standard. It was found that the product of methyl ester meets the standard of parameters determined. In this work, the measurement of biodiesel referring to ASTM (American Society for Testing and Materials). Authors had carried out the combustion testing for biokerosene, which was filled in a torch. The combustion showed the good result since there was not smoke appearing. It was indicative that the combustion process was perfect and the fuel was environmentally friendly.

Table 3. Comparisons biodiesel production with biodiesel standard

Physical properties	Unit	Sample	(SNI-2012)	(ASTM)
Relative density	gr/ml 25 °C	0.86	0.85-0.89	-
Viscosity	mm ² /s, 40°C	2.88	2.30-6.0	1.90-6.0
Sulfur content	%	0.0072	<100	-
Yield	%	97.76	-	-
Acid number	mg.KOH/gr	0.056	< 0.80	< 0.80
Water content	%	0.049	<0.05	<0.05

4. Conclusion

The biofuels, biodiesel and biokerosene were successfully prepared using the microwave, which decreased the reaction time. It was found that the greater the power used was the lower of yield of biodiesel obtained. The highest yield was 97.76 %, or 99.05 % conversion at power 100 W for 5 min using 1% NaOH. The methyl ester biodiesel and biokerosene were separated applying vacuum distillation at 185°C and distillate (biokerosene fraction) obtained was 48%. In general, the quality of products meets the standard numbers as required by ASTM.

References

- Chen, K. S., Lin, Y. C., Hsu, K. H., & Wang, H. K. (2012). Improving Biodiesel Yield from Waste Cooking Oil by Using Sodium Methoxide and a Microwave Heating System. *Energy*, 38, 151-158. <http://dx.doi.org/10.1016/j.energy.2011.12.020>
- Chowdhury, K., Banu, L. A., & Khan, S. A. L. (2007). Studies on the Fatty Acid Composition Of Edible Oil, *Bangladesh J. Sci. Ind. Res*, 42(3), 311-316. IFST, BCSIR, Dhaka-1205, Bangladesh.
- Dorado, M. P., Ballesteros, F., Lopes, F. J., & Mittelbach, M. (2004). Optimization of Alkali Catalyzed Transesterification of Brassica Carinata Oil for Biodiesel Production. *Energy Fuel*, 18, 77-83.
- El Sherbiny, S., Refaat, A. A., & El Sheltawy, A. T. (2010). Production of Biodiesel using Microwave Technique. *Journal of Advance Research*, 1, 309-314. <http://dx.doi.org/j.jare.2010.07.003>
- Galema, A. S. (1997). Microwave Chemistry. *Chemical Society Reviews*, 26, 233-238. <http://dx.doi.org/10.1039/cs9972600233>
- Gude, V. G., Patil, P., & Guerra, E. M. (2013). *Microwave Energy Potential for Biodiesel Production*. Mississippi State University, Chemistry Central, USA, 2013. <http://dx.doi.org/10.1186/2043-7129-1-5>
- Handayani, A., & Ariyanti, D. (2012). Potency of Solar Energy Applications in Indonesia. *Int. Journal of Renewable Energy Development*, 1(2), 33-38.
- Hsiao, M. C., Lin, C. C., & Chang, Y. H. (2011). Microwave Irradiation Assisted Transesterification of Soybean Oil to Biodiesel Catalyzed by Nanopowder Calcium Oxide. *Fuel*, 90, 1963-1967. <http://dx.doi.org/10.1016/j.fuel.2011.01.004>
- Jiputti, J., Kitiyanan, B., Rangsunvit, P., Bunyakiat, K., Attnatho, L., & Jenvanipanjakul, P. (2006). Transesterification of Kernel Oil and Crude Coconut Oil by Different Solid Catalysts. *Chemical Engineering Journal*, 116, 61-66.
- Lidstrom, P., Tierney, P., Wathey, B., & Westman, J. (2001). Microwave Assisted Organic Synthesis-A Review. *Tetrahedron*, 57, 9225-9283.
- Oliveira, A. N., Costa, L. R. S., Pires, L. H. O., Nascimento, L. A. S., Angelica, R. S., Costa, C. E. F., Zamian, J. R., & Filho, G. N. R. (2013). Microwave Assisted Preparation of a New Esterification Catalyst from Wasted Flint Kaolin. *Fuel*, 103, 626-631. <http://dx.doi.org/10.1016/j.fuel.2012.07.017>
- Pathil, P. D, Gude, V. G, Camacho, L. M., & Deng, S. (2010). Microwave Assisted Catalytic Transesterification of Camela Sativa Oil. *Energy Fuels*, 24, 1298-1304. <http://dx.doi.org/10.1021/ef9010065>
- Saifuddin, N., & Chua, K. H. (2004). Production of Ethyl Ester from Used Frying Oil: Optimization of Transesterification Process Using Microwave Irradiation. *Malaysian J. Chem*, 6, 77-82.
- Tippayawong, N., & Sittisun, P. (2012). Continuous Flow Transesterification of Crude Jatropha Oil with Microwave Irradiation. *Scientia Iranica B*, 19(5), 1324-1328. <http://dx.doi.org/10.1016/j.scient.2012.08.004>
- Zabeti, M., Daud, W. M. A. W., & Arroua, M. K. (2010). Biodiesel Production using Alumina Supported Calcium Oxide: An Optimization Study. *Fuel Processing Technology*, 91, 243-248. <http://dx.doi.org/10.1016/j.fuproc.2009.10.004>

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