CPO Based Biodiesel Production using Microwaves Assisted Method

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Abstract. Biodiesel is an alternative fuel for diesel engines produced by the transesterification of vegetable oils or animal fats with short chain alcohols such as methanol. The reaction requires a catalyst which is generally a strong base, thus producing a new chemical compound called methyl ester (Van Gerpen, 2005). One of the most common sources of biodiesel feedstock is CPO (Crude Palm Oil). CPO production in Indonesia is very high at 30.2 million tons in 2016, but CPO prices are low. Biodiesel can be produced using conventional methods, this method is less efficient because of its very slow and inefficient heating resulting from the transfer of energy to materials that depend on the convection currents and the thermal conductivity of the reaction mixture (Refaat and El Sheltawy, 2008) which causes researchers to use new methods of producing Biodiesel, that is by using microwave radiation method. Microwaves are used to emulsify two or more solutions that are difficult to mix (Gunawan, 2003). The advantages of using microwave radiation in the process of making biodiesel are heating faster, more energy efficient, and homogeneous heating. The mol ratio of CPO and methanol is varied to determine the effect of microwave power quality. The power of microwave used is 100, 180, 300, 450 and 600 Watt.

1. Introduction
Biodiesel is one of the biomass fuels that can replace fuel oil. One of the advantages of biodiesel fuel is that it is a renewable energy source that is more environmentally friendly than fossil fuels because biodiesel significantly reduces greenhouse gas emissions compared to fossil fuels [1]. Biodiesel has the potential to solve energy problems in developing countries, especially non-oil producing countries because most of the countries are turning to coal to spur their economic growth. Coal is the cheapest energy source, but coal is also the dirtiest source of energy. If developing countries can apply the use of biodiesel fuel, it can reduce pollution levels of coal power plants, and reduce their impact on climate change globally [2].

According to Indoenergi, one source of biodiesel raw material that is often used is CPO (Crude Palm Oil). CPO production in Indonesia is very high reaching 30.2 million tons in 2016, but CPO prices are low [3,4]. Therefore, it is necessary to process CPO into downstream products to provide high added value and have a much higher price than the initial commodity. One of the diversifications that can be done is the conversion of CPO into biodiesel.

Therefore, efforts to process CPO into downstream CPO products are needed to be converted into biodiesel by going through the esterification stage first and then proceed with transesterification. The
esterification process was carried out aimed at removing the levels of free fatty acids in CPO so that it would affect the purity of the biodiesel obtained in the transesterification process [5]. The transesterification process is reacted between oil molecules and alcohol and catalysts so that methyl esters are obtained [6]. To convert the oil molecule into biodiesel, a method that can convert oil in high quantities is needed. The method that is often used to convert oil to biodiesel is the conventional method [7]. Unfortunately, the use of this method is not efficient because the heating is very slow and inefficient due to energy transfer [8]. To materials that depend on convection currents and thermal conductivity of the reaction mixture [9]. Besides conventional methods, there are also other methods of producing biodiesel, namely by using microwave radiation methods [10]. Thus giving high added value and having a much higher price than the initial commodity. One of the diversifications that can be done is the conversion of CPO into biodiesel.

Microwaves or microwaves are electromagnetic waves that are in the frequency level from 0.3 to 300 GHz. Microwaves are used to emulsify two or more solutions that are difficult to mix [11]. The advantages of using microwave radiation in the process of making biodiesel are heating that are faster, more energy efficient, and homogeneous heating [12]. Heating using microwaves is faster because heat transfer is not carried out through the reactor surface, but by the absorption of wave, emission by the sample so that the sample temperature is higher than the surface temperature of the reactor wall [13]. This heating process is also influenced by the microwave power used. Based on Prayanto's research the best microwave power in the biodiesel production process is 800 Watt with a percent yield of 89.55% [14]. Meanwhile, according to another research, the best microwave power is 400 Watts so that the biodiesel production is 91.77% [15-16]. This percentage of yield is expected to be increased to reach more than 93 percent [17].

Based on the method above, a method will be developed to produce higher percent yield of biodiesel with variations in the mole ratio of CPO and methanol used in the esterification process using microwave technology [18]. Biodiesel production through this method can reduce waste in the surrounding environment and save energy use used for biodiesel production with high percent yield [19].

2. Materials and methods
2.1. Experiment treatment
In the analytical research of biodiesel yield percentage using microwaves radiation method, there are several variables specified, including fixed and changed variables. Fixed variable in the form of feed flow rate (ml), catalyst concentration (%) as well as microwaves power (Watt) while the changed variable is taken is the mol ratio between CPO and methanol in the transesterification process.

2.2 Experimental procedure
In making Biodiesel using CPO using the microwave method first the oil tank is filled with CPO as much as 5 liters, then put sulfuric acid (H₂SO₄) as a catalyst along with methanol poured in the catalyst + methanol tank. After the ingredients have been put into the tank valve which is in the oil tank open to drain the oil into the emulsifier. After all the oil is in the emulsifier, the valve of the catalyst tank is opened to drain the catalyst and methanol into the emulsifier. The stirring motor is turned on to do stirring, so the mixture is more evenly distributed. The next step, microwave by varying the power of 100: 180: 300: 450: 600 (watts). After the temperature of the mixture reaches 60-65°C, then the flow valve that leads to the reactor and the bypass flow valve is opened, the transesterification reaction will run according to the specified operating time. Then, the flow valve leading to the half is opened while the valve bypass is closed to close the flow back to the emulsifier. The mixture will meet the separator and separation is carried out using a 12 Volt high voltage within 10 minutes. After that two layers are formed, separated by the lowest layer (glycerol) by opening the valve separator which is below so that the glycerol we get can be carried out in the next stage, namely purification.
Figure 1. Design of Biodiesel Production using Microwaves Assisted

where A is the oil tank, B is the catalyst tank, C is the emulsifier, D is the microwave, E is the control panel, and E is the separator.

3. Results and discussions
3.1. Effect of CPO mol ratio: methanol to biodiesel yield (%)
The relationship between microwave power and biodiesel yield (%) can be seen graphically in the picture below.

![Graph showing the relationship between microwave power and biodiesel yield.](image)

Biodiesel Yield (%) vs. Microwave Power (watt)

In figure 2, it can be seen that at 100 watts of microwave power produces biodiesel yield (%) as much as 77.27%, microwave power at 180 watts produces biodiesel yield (%) as much as 79.62%, microwave power at 300 watts produces biodiesel yield (%) as much as 83.94%, microwave power at 450 watts produces 87.29% biodiesel yield (%), and microwave power at 600 watts produces 89.09% biodiesel yield (%).
biodiesel yield (%). This shows the relationship between microwave power and biodiesel yield (%). The greater the microwave power used, the greater the biodiesel yield (%) is produced. This occurs because the increase in alcohol to CPO will also increase the conversion into biodiesel. The transesterification process functions to replace glycerol alcohol groups with simple alcohol such as methanol or ethanol. Transesterification is an equilibrium reaction. To encourage the reaction to move to the right in order to produce methyl esters, it is necessary to use excessive amounts of alcohol.

3.2. Effect of microwaves power on the generated biodiesel density

Based on the observational data it shows the generated/produced biodiesel density has met SNI-04-7182-2006 biodiesel quality standards of 0.85-0.90 gr/ml. The ratio has an influence on the density value. The graph of relationship type and catalyst concentration to density can be seen in the figure below.

![Graph of relationship type and catalyst concentration to density](image)

**Figure 3.** The graph of relationship type and catalyst concentration to density.

Based on the graph above it can be seen that there is a decrease in density to 0.896-0.885 gr/cm³. According to the SNI biodiesel standard, the density is still permissible, at 0.85 - 0.90 gr/cm³. The lowest biodiesel density obtained is 0.885 gr/cm³, obtained from the mol ratio of 1: 2. While the highest density is 0.896 gr/cm³, obtained from a ratio of 1: 6. The higher the methanol mol ratio, the lower the biodiesel density is produced. This can be caused by increasing reaction rates and shifting of the equilibrium reaction. With the increasing conversion rate of triglycerides to methyl ester, the biodiesel density will decrease because the density of methyl esters is lower than the density of triglycerides.

3.3. Effect of CPO mol ratio: methanol on biodiesel flash point

Based on observational data and characteristic analytical data that have been carried out in appendix 1 and table 10, shows that the biodiesel flash point produced has met the biodiesel quality standard SNI-04-7182-2006 that is at least 100°C. The CPO mol ratio and methanol affect the resulting flashpoint where the flash point is high at a ratio of 1: 6 and has decreased to a ratio of 1: 2. As for the voltage graph against the flash point can be seen in figure 4.
The occurrence of an increased flash point value is due to the possibility of water level or the amount of glycerol and residual catalyst as well as alcohol in biodiesel. The difference that occurs in flash point might be caused due to the presence of residual form of glycerol and the remaining catalysts that have not been completely worn away and this can be caused by the presence of components in the biodiesel with a high flash point increase, so it raises the biodiesel flash point value. In this case, the used cooking oil is one of the possible causes of high flash point values.

3.4. Effect CPO : methanol ratio on the generated biodiesel water level
Based on observational data and characteristic analytical data that have been carried out, it represents the produced biodiesel water level mostly does not meet the SNI-04-7182-2006 biodiesel quality standards which are a maximum of 0.05%. Voltage affects the water level of biodiesel produced. Based on voltage variations used in table 5, it is seen that most of the water level produced does not meet the standards.

Based on the variation of the mol ratio used, the biodiesel water level at a ratio of 1: 2, the generated water level increases with the addition of methanol mol ratio of 1: 6. The high level of biodiesel water is caused by the accumulation of water in the oil before the transesterification process [15]. This increased water level can stimulate the hydrolysis process between triglycerides and water.
molecules to form glycerol and free fatty acids. The water level contained in the fuel can form crystals that may clog the flow of fuel [13]. The presence of water can also trigger the growth of microorganisms which certainly can clog the flow of fuel. Based on the effect tension graph on the water level in figure 4, it can be seen that the effect of the mol ratio on the suitable water level for biodiesel is at a ratio of 1: 2 and 1: 3.

3.5. Effect of CPO: methanol ratio on the generated biodiesel viscosity

Based on observational data and characteristic analytical data that have been carried out in the appendix and table 9, it shows that the produced viscosity does not meet the SNI-04-7182-2006 biodiesel quality standards that is a maximum of 6.0 cSt (centistoke).

Ratio variation affects the generated biodiesel viscosity. Based on the used voltage variations, it can be seen from the table that the biodiesel viscosity produced does not meet the SNI-04-7182-2006 biodiesel quality standards. Based on the effect tension graph of biodiesel viscosity produced can be seen in figure 6.

![Figure 6](image.png)

**Figure 6.** Graph of the relation between viscosity and methanol ratio.

The high viscosity is caused by the remaining remnants and glycerol, the heating temperature is too low, so the biodiesel viscosity does not decrease and also the quality of the used cooking oil raw material is not good enough. The difference viscosity in produced biodiesel is due to some impurities that are still contained in biodiesel in the form of unreacted reactants. Fuel atomization is highly dependent on viscosity, injection pressure, and injector hole size. Higher viscosity will make atomized fuel into larger droplets with high momentum and tend to collide with relatively cold cylindrical walls.

Based on the catalyst type and concentration graph on the relationship Viscosity in figure 5, it can be seen that the variation of the good mol ratio for biodiesel as seen from the produced biodiesel viscosity is a mol ratio of 1, 2 volts.

5. Conclusions

Biodiesel with a ratio of 1:6 produces the highest yield (%), namely 89.12%. A good variation to produce biodiesel in accordance to the SNI-04-7182-2006 biodiesel quality standards is a ratio of 1:6 with yield (%) of 89.12%, density of 0.885 gr / ml, flash point of 197.6°C, water level of 0.81%, viscosity of 10.543 cST, and heating value of 0042,793 cal/gr. A biodiesel maker with a continuous system is produced. Where the produced biodiesel is seen from the yield (%), density, flash point, water level, and heating value, most of them meet SNI-04-7182-2006 standards except the viscosity that passes the maximum limit of viscosity values based on SNI-04-7182-2006 standards.
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