Making of Palm Oil into Biodiesel Catalyzed by CaO aided by Microwave Heating

Rangga.S.[1], Susila Arita[1]*, Attaso.K [2]

[1]Department of Chemical Engineering, Faculty of Engineering of Sriwijaya University
Jl. Raya Inderalaya Km.32, Inderalaya, Ogan Ilir, Sumatera Selatan 30662.
Corresponding author : susila_arita@yahoo.com

ABSTRACT

Biodiesel is one of the alternative fuels. Biodiesel can be made from palm oil and the other raw materials. This research studies the optimum condition of palm oil (RPO) production by methanolysis reaction of heterogeneust catalyst calcium Oxide (CaO) aided by microwave irradiation. In order to get optimum condition, pretreatment catalyst has been done in $500^{o}C$ at 1 hour. FFA removal can be reduced until 0,2% by esterification . The result of biodiesel was analyzed by Gas chromatography to measure the total of methyl esters conversion. The optimum condition for transesterification was 400 watts and catalyzed by 5% of CaO of weight oil, have the yield of biodiesel 75,60% and the conversion of methyl esters 92%.

Keywords: Biodiesel, Palm Oil, Heterogeneust Catalyst, Microwave,Calcium Oxide

1.Introduction

During the energy crisis, high oil prices and environmental concerns was prompted the government and the community to establish a national energy policy with an emphasis on renewable energy such as biodiesel to reduce fossil fuel consumption and to increase the energy security of the country. In Thailand and Indonesia, palm oil is one of resources which has a high potential of biomass as a renewable energy source for the production of biodiesel. The most commonly catalyst in the manufacture of biodiesel is homogeneous catalysts, but it's not so popular these days because of the difficult separation process. So the alternative is a heterogeneous catalyst which is considered more economical and easier in the separation of the biodiesel product._(Herman.S & Zahrina.I, 2006)

1.1 CaO as Heteregenoust Catalyst

One of the heterogeneous catalysts that can be used in mehtanolysis reaction is calcium carbonate ($CaCO_3$) which burned at a certain time and temperature into Calcium Oxide (CaO). Typically, both a strong base and a strong acid catalyst can be used for the transesterification of triglycerides and short alcohol in a homogeneous system. Therefore, many types of solid catalysts such as alkali oxides and hydroxides, has been reported in the manufacture of biodiesel for green environment (Kawashima et al., 2008) .

Transesterification by acid catalyst perhaps be the best choice for the raw material with high FFA content but it takes a long time and cause corrosive to equipment. Therefore Alkaline catalyst reaction is inevitable (Canakci and Van Gerpen, 1999). izuka et al have been done a project and research paper was reported that CaO is one of the alkaline earth metal oxides are formed from ionic crystals. Zhu et al (2006) have obtained 93% conversion of Jatropha oil using a solution of ammonium carbonate with CaO. Watkins et al (2004) introduced the basicity of CaO with lithium doping. (Reddy et al., 2006) have been testing nanocrystalline CaO in biodiesel production within temperature room which show that the first three cycles gave more than 99% conversion, but the conversion decreased in the fourth and fifth cycles.

1.2 Microwave in Biodiesel Production

Waves at a frequency of 2,500 MHz (2.5 GHz) is absorbed by water, fats, and sugars. When absorbed, atoms will be excited and produces heat. This process does not require heat conduction as usual. That's why the process can be done very quickly. Amazingly, microwaves at this frequency is not absorbed by the materials glass, ceramics, and some types of plastic. Metal is even reflected wave. Heating by microwave has the advantage that is more equitable ,instead of transferring heat from the outside but generate heat inside the material. Heating can also be selectively depends on the dielectric

properties of materials. It will save energy for heating (Handayani,S.P. 2010).

Microwave heating mechanism is complex. Comparison with conventional heating method would provide the differences in heating mechanisms and the advantages of microwave heating. In conventional heating as well as supercritical methods, heat transferred to the sample volume that's utilized to increase the temperature of the surface from the vessel followed by the internal materials. Therefore, a large portion of energy supplied through conventional energy source is lost to the environment through conduction of materials and convection currents. Heating effect in the heterogeneous conventional method is depend on thermal conductivity of materials, specific heat, and density which result in higher surface temperatures causing heat transfer from the outer surface to the internal sample volume. As a result, non-uniform sample temperatures and higher thermal gradients are observed (Bogdal D, 2005).

2. Materials and Methods
2.1 Chemicals

Cooking Palm oil was purchased from Nakhon Si Thammarat, Thailand. Methanol (≥98%) was purchased from MERCK (Malaysia) and sulfuric acid 96% (Carlo Erba Group). NaOH 99% (RCI Labscan Ltd), Calcium Oxide (CaO) 96% was purchased from Ajax Fine Chem Ltd. For Gas Chromatography, N-hexane (≥96%) used as a solvent for GC analysis was purchased from MERCK (Malaysia). All the chemicals used were analytical reagent grade.

2.2 Preparation of Catalyst

Calcium Oxide is a heterogeneous base catalyst with very small tolerances in the open air, putting CaO in the open air will cause the CaO absorbs CO_2 in the air and turned into $CaCO_3$, if it's not avoided in the process in making of biodiesel, it will cause the catalytic process being weak . To solve the problem, preparation should be done before using it. CaO catalyst was burned in a furnace about 500°C in one hour, it is intended to remove the water content of the catalyst and also emit CO_2, thus would be obtained pure CaO. after that CaO was mixed with methanol before methanolysis reaction and stirred for 15 minutes at 400 rpm as a treatment before transesterification carried out.

2.3 Experimental Procedure
2.3.1 Esterification (FFA Removal)

First of all Refined Palm Oil (RPO) was weighed on Sartorius balance as much as 100 grams, then mixed with methanol at a molar ratio of 18:1, 18 for methanol and 1 for oil. Sulfuric acid catalyst was taken 3% of weight of oil as much as 4.1 ml, three ingredients were dissolved and the mixture was refluxed for 1 hour at a temperature of 65°C, the temperature was maintained until the reaction was complete. After the solution was poured into a separating funnel to separate methanol, residual catalyst, and oil. The solution was left for 24 hours to obtain a product of esterification. The results can be seen after 24 hours, the oil in the bottom of the product with the FFA has been reduced and the top layer is unreacted methanol and residual sulfuric acid. Valve was opened in separating funnel to separate the product from methanol and sulfuric acid which are on the top layer.

2.3.2 Determination of FFA Content

In this case the titration was performed. 5 g of esterified oil was weighed and then added to a 250 ml Erlenmeyer flask with 50 ml of ethanol (98%). The solution was added by 2 drops of phenolphthalein indicator, then the mixture was titrated with NaOH 0.1 M. Titration was done until the solution changes its color into pink. NaOH was reduced due to titration recorded and FFA can be calculated with this equation (SNI 01-3555-1998)

$$FFA\ (\%) = \frac{Mw(fa).V.N}{10.m\ oil}$$

Where Mw (fa) is molecular weight of palmitic acid (256,42 g/mol), V is NaOH volume has been reduced due to titration, N is molarity of NaOH (0,1 M), and m is oil weight (5 gr).

2.3.3 Transesterification Aided by Microwave Heating

After the preparatory phase of the Methanolysy was completed, methanol and catalyst was mixed with oil that has dissolved into esterified. oil and methanol was mixed with a molar ratio of 18: 1, 18 for methanol and 1 to oil. The solution was reacted in a 250 ml reaction flask with a set of reflux tools. Microwave conventional has been modified by making holes in the top of the microwave as a place to put the condenser, the reaction was run for 20 minutes for each sample and the microwave power set at 200 watts for samples with 1% of catalyst, 3%, 5% by weight oil and then 300 watts for samples with 1% of catalyst, 3%, and 5% and 400 watts for samples with 1% of catalyst, 3%, and 5%. Solution was stirred at the same velocity for each sample was 600 rpm. after the reaction was complete, the solution was allowed to stand in a separator funnel for 6 hours, then observed.
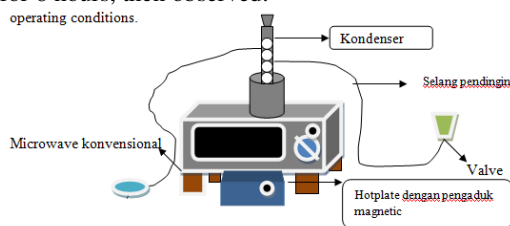

Fig 1. Design of Equipment

2.3.4 Catalyst Separation, Washing, and Drying of Biodiesel

When Transesterification has complete, glycerol and catalyst was separated from the biodiesel by opening the valve in separator funnel. In this case, impurities and residual catalyst were still contained in the crude biodiesel. Therefore, it was filtered using a vacuum filter to separate solids and liquids. After the catalyst and impurities was filtered, clean biodiesel was obtained. Biodiesel was inserted again into the separator funnel and washed with distilled water which previously was heated around 55-60°C within ratio 1:1 between oil and water. Washing was done 2 times and the solution was allowed to stand for 5 hours. Soap and impurities will be seen remaining on the bottom layer, then separated from the biodiesel and biodiesel dried in an oven about 90°C for 6 hours to remove the water contained. After that biodiesel was observed in physio-chemical properties and analysis of Gas Chromatography.

2.3.5 Analysis
2.3.5.1 Measurement of Free Fatty Acid (FFA) and Acid Number

Titration was performed to measuring FFA and acid number content in Biodiesel. 5 g of oil was added in 250 ml Erlenmeyer flask and 50 ml of ethanol (98%) was added. Phenolphthalein indicator was added as much as 2 drops into the solution, then the mixture was titrated with NaOH (0,1M) in 25ml of burette. Titration was done when the color of the solution changed into pink. After that calculated the FFA with the equation (SNI 01-3555-1998)

$$FFA\ (\%) = \frac{Mw(fa).V.N}{10.m\ oil}$$

Where Mw (fa) is molecular weight of palmitic acid (256,42 g/mol), V is NaOH volume has been reduced due to titration, N is molarity of NaOH (0,1 M), and m is oil weight (5 gr).

For Acid Number measurement can be calculated with the equation below :

$$\%\ FFA \times \frac{Mw\ NaOH}{Mw\ Pal\ Acid:10}$$

Where Mw NaOH is molecular weight of NaOH (39,9971 g/mol), V is NaOH volume has been reduced due to titration, N is molarity of NaOH (0,1 M), and mw pal acid is molecular weight of palmitic acid (256,42 g/mol)

2.3.5.2 Density Measurement

The working principle of the density measurement is the ratio of the mass of sample without the air at a certain temperature and water volume at same temperature and mass volume. Empty Pycnometer was dried in an oven and be weighed, then Pycnometer was filled with distilled water with temperature of 20°C then stored in a water bath at 25°C for 30 minutes. It has been Soughted with no air bubbles in the Pycnometer that contain distilled water and the sample neither. Pycnometer

then will be dried, and weighed. Weight of distilled water obtained from the difference Pycnometer contains Pycnometer distilled water and empty pycnometer. In the next stage sample was cooled in temperature 20°C. Then put oil in Pycnometer , previously cleaned and dried to overflow the water and no air bubbles are formed. The outside Pycnometer was dried and placed in a water bath at a temperature 25° C for 30 minutes. Pycnometer removed from the water bath and then dried, and weighed. Weight of the sample is obtained by calculating the difference in weight of the sample and weight of empty pycnometer. (SNI – 06-4085-1996).

Density could be calculated by this following equation :

$$\frac{W1}{W2}\ x\ \rho\ water$$

Where, W1 is Sample weight (g), W2 is Distillate water weighted (g), ρ water is Water density (1 g/ml).

2.3.5.3 Yield Measurement

Yield percentage can be calculated by this following equation :

$$\frac{weight\ oil\ of\ product}{weight\ oil\ of\ feed}\ x\ 100\%$$

Where Weight oil of product is scale the weight of oil after washing and drying, Weight oil of feed isoil for feed stock (100 gr)

2.3.5.4 Gas Chromatography Analysis

Biodiesel that has been obtained was characterized by Trace Gc to knowing compounds and calculating the conversion of Biodiesel, in this case, Trace Gas Chromatograph was used by mixing 0,2 ml of oil and 2 ml of hexane in sample's tube and after that machine will be analyze automatically. Injector temperature and detector set at 365 and 370°C. Temperature column maintained at 80°C, increased to 370°C at a rate of 15°C/min and was kept at 370°C for 10 minutes. Used 1:50 split ratio on pressure 60 kPa with nitrogen as gas carrier.

3.Results and Discussion
3.1 Esterification of removing FFA

In the manufacture of biodiesel using refined palm oil as raw material had was found that the free fatty acid content is still high enough to conduct methanolysis reaction, before it will be done, we need to reduce the levels of free fatty acids in palm oil by converting free fatty acids (FFA) into esters by esterification reaction. Amount of methanol with molar ratio with oil (18:1) was added to 100 gr oil and 3% sulfuric acid (H_2SO_4), and esterification was held by conventional heating during 1 hour at 70°C (Buathip T et al, 2013), it has known the oil content as much as 1.06% and after the reduction of FFA through the esterification, free fatty acids (FFA) has been turned into 0,20%. According to Garpen

(2004) FFA content is allowed in the base catalyst is <1% or equivalent with 2 mg KOH / g sample (Berrios, 2007). Esterification reaction need amount of methanol and acid catalyst to change FFA into esters. In otherwise Acid catalyst was used for this reaction because it can't make saponification with high FFA and can be produced high percentage of biodiesel's yield.

3.2 Making of Biodiesel Aided by Microwave Heating

3.2.1 The Influence of Microwave Irradiation and CaO at yield of biodiesel

The study of Making Biodiesel from conventional batch heating has been done by a lot of people and it can be more expensive because of high energy and timing of process, Padil (2010) has done the experiment about transesterification with vegetable oil using CaO with conventional batch and he has a result of methyl ester conversion about 73,03% and yield about 73,38% by 105 ^{o}C and reaction time 1,5 hours. It means using conventional heating need long time reaction to make FAME, we can reduce all of that with Microwave. In this case Microwave conventional was used for batch reactor scale. Batch method have some advantage if we compare with continous method because of easier in process control and don't need a lot of equipment. Transesterification need a lot of methanol to change triglyseride into methyl ester, that's why it was using high molar ratio between methanol and oil (18:1), it will make balance of reaction will move to product and make higher conversion of methyl esters, because 3 mol of alcohol will turn into 1 mol of glycerol (Bradshaw and Meuly, 1994). Transesterification was done with various of catalyst 1%,3% and 5 % to each sample and also the power of microwave 200 watt,300 watt,and 400 watt. The duration of each reaction was 20 minutes and was stirred in 600 rpm.

The main product of methanolysis were biodiesel (methyl ester), and have excess of glycerol and soap products. Normally the process of making biodiesel with heterogeneust catalyst will the make 3 layers, the bottom is glycerol and at the top is the product (biodiesel), but from this experiment was founded 4 layers with microwave heating under 300°C. At the top was an excess of methanol, which has not been converted yet, in the middle was biodiesel, in the 3rd layers was glycerol and in the 4th layer was a catalyst. I assumed at the low temperature methanol was converted into biodiesel was not enough yet, because of the short reaction time. But at the 300°C-400°C, all of the methanol has been converted into biodiesel and only produce 3 layers. Top was biodiesel, 2nd and 3rd layer was a layer of glycerol and catalyst. The result was showing that the yield of the product can be seen in the graph below.

We can see from the picture that show the highest yield conditon in 300 watt and catalyzed by 1% of CaO have 91% of yield and the lowest yield condition at 200 watt and catalyzed by 1% of CaO, which have only 60,48% yield, it means 300 watt is better than 200 watt for process condition. The power condition was studied by Putra R.P et al (2012), they was found the yield result about 60,11% in 20 minutes reaction at 200 watt and catalyzed by 1% of CaO. But for the reaction condition with temperature 300 watt and concentration of catalyst 3%,5%, the yield of biodiesel has reduce into 86,6% and 77,34%. It was suspected that biodiesel was wasted when washing of biodiesel has been done. Because based on the graphic above that 200 watt and 400 watt condition, yield of biodiesel was going up for the higher catalyst.
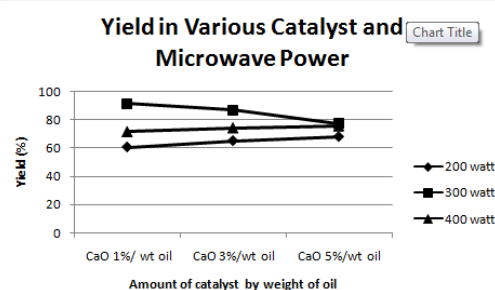
Fig 2. Graph of Yield in Various catalyst and Microwave Power

The using of catalyst can affect the results obtained. In terms of duration and temperature of the reaction depend on the characteristics of each catalyst. The study was using the NaOH as homogeneous alkaline catalyst to form biodiesel yield by 98% on the 264 Watt and the average operating temperature of 50.5°C for 2 minutes. (Santoso and Wijaya, 2009). As we know homogeneust catalyst will make the higher of yield but consume more price and difficulty of separation.

3.2.2 Analyzing of FAME in biodiesel conversion by Gas Cromatography

Analysis by Gas Chromatography (AS 2000) was used to determine the types of compounds that contained in the methyl ester of palm oil, and to calculate the percentage of Fatty Acid Methyl Esters (FAME) in biodiesel. This analysis produces spectral peaks respectively indicate the type of methyl ester specific. Trace GC. Based on data from the GC, the various types of methyl esters for biodiesel can be determined. Analysis of biodiesel compounds made against fragmentation peaks that can be identified as biodiesel compounds based on similarity with standard compounds. A compound said to be similar to the standard compound if it has the same molecular weight, similar patterns of fragments, and the value of SI (similarity index) is high. To use GC

we need standard solution and also n-hexane and samples. In this experiment was used 2 ml of hexane and mixed with 0,2 ml of oil and after that it was filled in small bottles to analyzed by GC further and was connected to the computer software.

From table 1 is shown that Biodiesel from palm oil was compound the main substances of methyl ester, they were methyl palmitate, methyl palmitoleate, methyl stearate and methyl oleate which the highest conversion was owned by methyl palmitate because of this fatty acid is a highest compound of palm oil. The other compounds that was resulted from the analysis by Gas Chromatography. There was also unsaturated methyl ester, namely methyl ester palmitoleate (C16:1) although the percentage was very small. The conversion result was calculated of each samples from GC can be shown in the appendix. And the graphic below can describe about the amount of conversion.

Table 1. Content of Palm oil Biodiesel

No	Name of compound	Peak	Percentage (%)
1	C16:0 (methyl Palmitate)	1	9,8
2	C16:1 (methyl palmitoleate)	2	0,041
3	C18:0 (methyl stearate)	3	1,078
4	C18:1 (methyl oleate)	4	9,227

From fig.3, we can get the conclusion that the highest condition is 400 watt of microwave power and 5% Calcium Oxide by weight of oil. The other result for 400 watt condition showing the highest conversion than the others ,and in the same amount of catalyst as well. In the picture we can see that Biodiesel Conversion is too small for 200 watt and 300 watt. Handayani S.P (2010) has proven already about microwave in making of biodiesel with homogeneust base catalyst, At 300 watts of power, biodiesel has not been established. It is possible for a power that was given was still small, so it has not been able to react oil and methanol within 10 minutes. Biodiesel start formed on 400 watts of power and a mole ratio of oil to methanol at 1:12. The excess methanol from biodiesel that produced from 200 watts of power and 300 watts of power within 20 minutes also still have excess of methanol, in otherwise the convertion of methyl esters was not

perfectly formed. And for the 400 watts of microwave power was not found the excess of methanol in separation.

Conversion of Methyl Ester
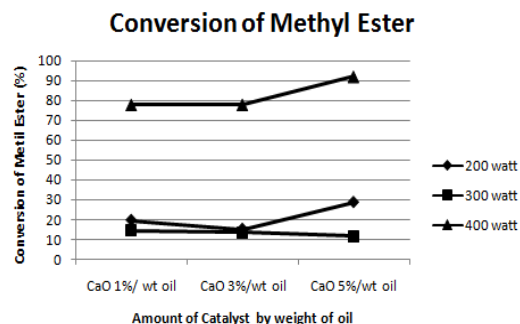
Fig 3. Graph of Conversion toward the amount of catalyst and microwave power

The equation to calculate the conversion of biodiesel is shown in the following equation below

$$C_{methly\_palmitate} = \frac{Area_{sample} \times Conc_{std.} \times V_{Hexane}}{Area_{std.} \times V_{sample} \times 1000 \times MW_{std.}}$$

ASTM Standard D6584-00 was used for calculation, and using methyl palmitate as basic calculation because of methyl palmitate is the most fatty acid that contained in biodiesel from palm oil. The equation above can be explained as :

Area sample is the area under graph of sample (1*uV*sec), Conc std is the concentration of standard substance (mg/L), V Hexane is the amount of hexane, Area std is the area under graph of standard substance (C18:0) (1*uV*sec), V sample is the amount of samples, MW std is the moleluce of standard substance.

It divide by 3 because of every 3 mols of methanol can produce 1 mol of glycerol.

$$\% \, Conversion = \frac{C \, 16{:}0 \, used \times 100\%}{C \, 16 : feed}$$

Where C 16:0 used is the concentration of methyl palmitate that was reacted (mol/L) C 16: feed is the concentration of methyl palmitate which has been done FFA reduction (mol/L). From the calculation, we get the highest percentage of biodiesel in 400 watt and 5% of catalyst, the result reach until 92%. That's mean it's the best condition for this experiment.

3.2.3 CaO in Biodiesel Production

The addition of the CaO as the heterogeneust catalyst still have a problem inside it, because of CaO is easier than the others to absorb CO_2 in the air and not resistant in the moist air. So we need the preparation before. Amount of Commercial CaO in the furnace was burned about 500^oC in a hour to avoid the moisture content in Calcium Oxide. The

calcinations also can remove the CO_2 from CaO paticles, so that it was forming a lot of pores in calcium Oxide. The size of CaO was used about 200 mesh, productivity will be better when the catalyst surface area per mass unit is bigger. Enlarge the surface area of catalyst per mass unit can be done by reducing the size of the solid catalyst. Mixing the methanol first and then pour into the amount of the CaO and it was stirring with 300-400 rpm in 10-15 minutes. To obtain the optimal conditions before reacted, CaO catalyst was activated by Methanol. Small amount of CaO will react with methanol and converted to $Ca(OCH_3)_2$ and $Ca(OH)_2$ but some CaO is left unchanged. Initially CaO will react with Methanol, And forming $Ca(OCH_3)_2$ and subsequently generated during the formation of H_2O. $Ca(OCH_3)_2$ will react with CaO to form $Ca(OH)_2$. (Ayato Kawashima, et al, 2009).

CaO catalyst is more active and has been studied for transestrification because the price is cheap, has a high strength base ($H_- = 26.5$) (Liu et al, 2008) and slightly soluble in methanol than oxides or alkaline earth metal hydroxides such as SrO and Ba $(OH)_2$ which fully dissolved in the media of reaction (Granados et al, 2007). In the study that conducted by Granados et al (2007) concluded that although CaO is very active in the transesterification reaction, but the catalytic is the result of contributions heterogeneous and homogeneous, that is pervasive in part small CaO in the media of reaction.

3.2.4 The Analysis of Acid Number

The high value of acid number can make a new problem for biodiesel product. According to Diaz and Galindo (2007), the ideal diesel engine fuel is the fuel with a hydrocarbon's chain entirely saturated. The acid number that owned in biodiesel of palm oil is also very low. it means Biodiesel contains free fatty acids were very slightly. Thus, biodiesel is not corrosive and does not harm the engine injector diesel. For the result of acid number,density and the other analysis can be seen in the fig 4.
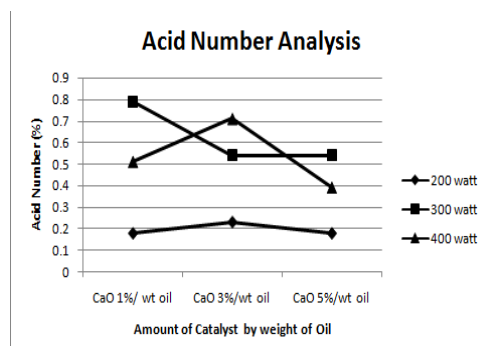

Fig 4. Graph of Acid Number Analysis

From the fig 4 is shown that the result of acid number in 200 watt and 400 watt with the same amount of the catalyst have suitable with the standard of biodiesel in ASTM D-6751 that allow the highest of acid number is 0,5%. The addition of the catalyst affected the value of acid number in 200 watts of microwave power was shown the amount of catalyst 1% have the acid number 0,18% and up in the addition of 3% CaO but it's down again when the addition of catalyst in 5%, the same condition 400 watts as well.it's possible that the highest addition of CaO can reduce the value of acid number and the best result in the 5% of CaO.

Density is the ratio of the mass of a substance at the volume certaining with temperature. In the lower temperature,so the density of biodiesel will be higher and and opposite. The presence of glycerol can influence the density in biodiesel, because biodiesel glycerol has a fairly high density (1.26 g/cm3). So if it is not well-separated by glycerol of biodiesel, biodiesel will increase the density. Density of biodiesel in this experiment can be seen in the table 4.2. it show that the watts of microwave power affect the density. the higher watts can reduce the value of density that's also influence by addition of CaO as catalyst, and the best condition to have standard density in European EN-12414 that shown in the 400 watts of microwave power have the minimum requirement is 860 kg/m^3 and the maximum is 900 kg/m^3, the catalyst in this condition was not influence the result .the graphic of the measuring of density can be seen in the fig.5.
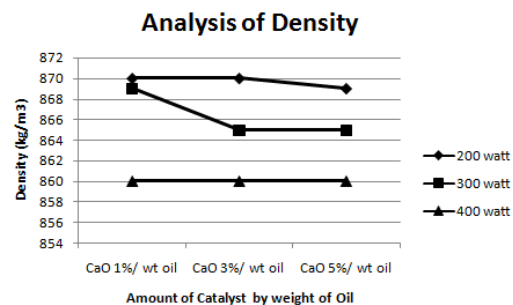

Fig 5. Graph of Density Measurement

In 400 watts of microwave power show that the result of density were 860 kg/m and catalyzed by 1%, 3%, and 5% of CaO. It's the best result if we compare with the standard of biodiesel European EN-12414. According to Prihandana et al., (2006), biodiesel has density exceeds the provisions will make combustion reaction not perfect. Thus can increasing emissions and make the diesel engine will be worn out. Biodiesel with a density of 860 kg/m3 can make perfect combustion.

4. Conclusion

From the results of research and discussion, it can be concluded as follows:

1. Microwave irradiation can be utilized in the process of making biodiesel from palm oil through batch of transesterification process .

2. The using of microwave heating in the manufacture of biodiesel from palm oil with the higher power is able to increase the yield of biodiesel. Optimum power is 400 watts in the mole ratio of palm oil with methanol at 1:18 and have yield of biodiesel 75,6% ,and for 300 watts of microwave's power data reduction have been found.

3. Microwave heating was proven that can reduce the time of reaction to be very short. The higher watt of microwave can increase the conversion of methyl esters. Optimum power is 400 watts on the mole ratio of palm oil with methanol at 1:18 and the conversion percentage reach 92% of FAME

4. The optimum condition in this experiment was 400 watts and 5% of CaO, which have better result than the others

5. From the various of CaO catalyst, was obtained that the optimum condition for this experiment is 5% of catalyst in 1:18 molar ratio of oil and methanol

6. The higher of CaO catalyst in 200 and 400 watts of microwave's power can increase the results of yield and conversion

7. The compound of biodiesel from palm oil in this experiment have been found from Gas Cromatography (AS 2000) as follows: methyl palmitate, methyl palmitoleate, methyl stearate, and methyl oleate.

5. Acknowledgements

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