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Pilot Plant Biodiesel From Waste Cooking Oil

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Abstract

Methyl ester or biodiesel is an alkyl ester compound that is produced through an alkoholic process (transesterification), between triglycerides methanol or ethanol with the aid of alkaline catalysts into alkyl esters and glycerol. Methyl ester is produced through a transesterification reaction between used cooking oil and methanol with a mole ratio of 6:1, the reaction is accelerated using base catalyst. The method used in the production of methyl ester is pilot plant batch scale which adopts a large scale industry with modifications according to the desired design. Base catalyst variations were carried out at 0,1% w/w, 0,3% w/w, 0,5% w/w, 0,7% w/w, and 0,9% w/w.The productions of methyl ester consists of three processes namely pre-treatment, transesterification reaction, and post-treatment. Quality test of methyl ester (post-tre atment) consists of density, kinematic viscosity, total glycerol, and acid numbers. Known from the result of the research, the overall quality of methyl ester are appropriate according to the Indonesian National Standard on Biodiesel.

Keywords: Biodiesel, Pilot Plant, Waste Cooking Oil, Transesterification

1. Introduction

This 21st century life makes people increasingly consumptive in using energy. Energy needs will be a primary necessity, if no renewal or alternative energy will cause instability between the raw material and the energy requirement. Energy is the ability to perform work, the power used to perform various processes of activity. Energy has several forms and comes from anywhere e.g. electrical energy, light energy, chemical energy and others. Alternative energy is the substitute energy of energy itself. Alternative energy originated not from petroleum includes hydropower, geothermal, nuclear, solar, wind, wave, biomass, natural gas, peat, coal and natural gas. Where appropriate you should overtype the different fields with your own text. Make sure that as you do this the correct style for the current paragraph is still displayed in the style box on the menu bar. Please read through the following sections for more information on preparing your paper. However, if you use the template you do not have to worry about setting margins, page size, and column size etc. as the template already has the correct dimensions.

With the instability of energy production and consumption has changed the energy paradigm and forced the world adapt to achieve sustainable long-term energy security (Budiman, 2014). The world's consumption of petroleum diesel is 934 million tonnes per year (Atmaja, 2010). Knowing the condition of the Indonesian government began to seek alternative energy replacement of petroleum diesel by utilizing biomass from biofuels (BBN) derived from renewable natural resources such as methyl ester (biodiesel).

Methyl esters are alternative diesel fuels made from renewable biological sources such as vegetable oils and animal oils. Methyl esters can be biodegradable and nontoxic, and have low emissions as well as environmentally friendly (Atmaja, 2010). Indonesian region has a lot of potential raw materials producing methyl ester, covering oil palm, jatropha, oil, coconut oil, nyamplung oil, algae, etc (Densi, 2017).

The cooking oil is one of the raw ingredients of methyl ester. Cooking oil from the food industry and households are quite available in Indonesia. The sour oil is not good if it is reused for cooking because it contains a lot of free and radical fatty acids that can harm health. Used cooking oil can be the raw material of methyl ester but the used cooking oil has a free fatty acid content with a fairly high concentration, but the content can be reduced by reacting free fatty acids with catalysts.

Methyl esters of the barley oil are produced through the transesterification process. In the process of transesterification used cooking oil is reacted with alcohol (methanol) and a base catalyst will produce glycerol as a side product. This process has immiscible (not mixed) properties, therefore heating with heater and mixing with stirrer is necessary to homogenize the oil of the jelantah, alcohol and catalyst. The process of slurries (precipitation) occurs twice to precipitate the side products and water used to clean the methyl ester from the dirt that is still possible mixed.

The method used in this research is a pilot plant method of adopting from an industrial environment, expected the result of methyl ester close to the quality of the industry. With the advantages of production process of methyl ester through batch scale plant pilot method through transesterification reaction, it is expected to be the bridge between the transesterification process of oil in the laboratory scale and industrial scale.

2. Production Process of Methyl Ester

2.1 Methyl Ester (Biodiesel)

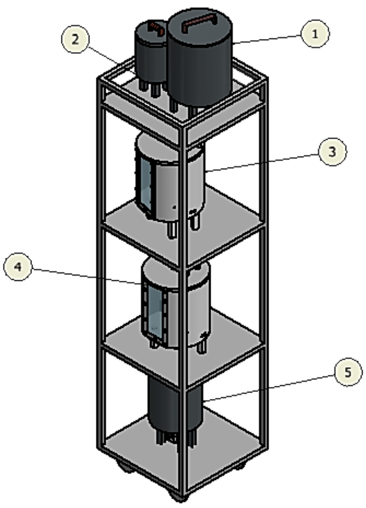
Methyl ester or biodiesel is an alkyl ester compound produced through the process of Alcoholis (transesterification), between triglycerides with methanol or ethanol with the help of base catalysts into methyl ester and glycerol. Excess methyl ester is among other untoxic fuels and biodegradation, high devil numbers, carbon monoxide emissions, hydrocarbons and NOx value small, phase in liquid form.

2.2 Raw Materials

Initially, the raw materials used for the manufacture of methyl esters are derived from vegetable oil such as edible oil, such as oil from soybeans, coconut oil, oil from sunflower seeds and many others, but gradually raises the issue Competition against the food security of a country. Therefore (Budiman 2014) the idea arises to create methyl esters from nonedible oils such as jatropha oil, nyamplung oil and castor oil. Because of pollution problems produced by nonedible material, other ideas arise to use microalgae as raw material of methyl esters that do not cause pollution and other environmental problems. In addition to the three materials above the other methyl ester material derived from low quality waste among other raw materials so it is required a long enough process to be converted to methyl ester. The use of waste cooking oil (used cooking oil) as the raw material of methyl ester aims to utilize the abundance of common oil amounts in the community.

2.3 Batch Scale Plant Pilot Method

The use of methods on this research is an industry adoption method. With another name of pilot plant. Pilot plant is a method of adoption of large scale factory modified according to the desired design. While the batch scale is a measure comparison in this study is intended the process of mixing oil and other materials in the manufacture of biodiesel. The molar ratio between alcohol and triglycerides is 4:1 to 20:1, but the most widely used ratio is 6:1. With operating temperatures ranging from 298 – 358K. Excess batch process is easy mixing of raw materials, efficient feeding of chemicals, and easy quality control.



1	Waste cooking oil's reactor
2	Catalyst's reactor
3	Reactor Transesterification and *Settling 1*
4	Reactor *Wahing* and *Settling 2*
5	Reactor *Drying* and Methyl Ester

Fig. 1: Pilot Plant Biodiesel

2.4. Transesterification process

In this study, using a base catalyst so that the chemical reaction used was transesterification. With another sense of transesterification reaction is the reaction between alcohol and triglycerides forming methyl ester and glycerol. Step transesterification process, among others: (i) the raw material is heated and stirring in tanks up to 60ºC temperature; (ii) the mixture is precipitized up to two phases between the glycerol and the crude methyl ester (process slurries 1); (iii) crude methyl ester will then be washed until normal pH (6.8-7.2) (washing process); (iv) performed re-deposition to separate water (process slurries 2); (v) heating methyl ester at 60ºC (drying process).

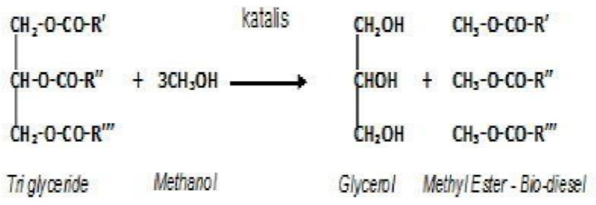


Fig. 2 : Transesterification process

3. Result and Discussion

Preliminary research is done by calculating the levels of free fatty acids (FFA) and the number of acids in oil. Known as FFA content of 0.5% so that it is still in terms of < 2%, then the process of transesterification is done. Density value of the equipment using the balance sheet and picnometer. Viscosity sampling is possible by the Ostward Viskometer method. Total glycerol and acid number by doing a base acid tiration.

Table 1 Standard SNI Biodiesel and Solar

Parameter	SNI Biodiesel	Solar
Density (kg/m^3)	850-890	859,9
Kinematic Viscosity (cSt)	2,3-6	4,17
Total Glycerol (%)	maks 0,05	0
Acid Number (mg-NaOH/gr)	maks 0,8	0

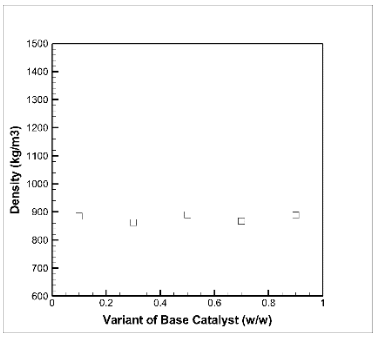


Fig. 3 : Influence of base catalyst variation on density

From Fig.3 shows the density value of methyl ester tends to increase in proportion to the increase in the concentration of the catalyst base. Factors affecting density include the concentration of basic catalysts and the purification process (washing and drying). The increase in base catalyst in the methyl ester mixture is proportional to the density, where molarity is the concentration of the solution obtained from the mole ratio of the solute to the volume of the solvent. Moles of the solute are broken down again into a ratio of the mass of the solute and the relative molar mass of a substance. Density is the ratio of mass of solute to volume. Then the density is directly proportional to the increase in base catalyst. The greater the catalyst concentration, the higher the density value will be.

Based on this study methyl esters with variations of base catalyst 0.1% w / w, 0.3% w / w, 0.5% w / w, 0.7% w / w, and 0.9% w / w value density is directly proportional to the concentration of methyl ester and the density value of methyl ester is in accordance with SNI Biodiesel, so it can be used as a diesel mixture for diesel engine fuel.

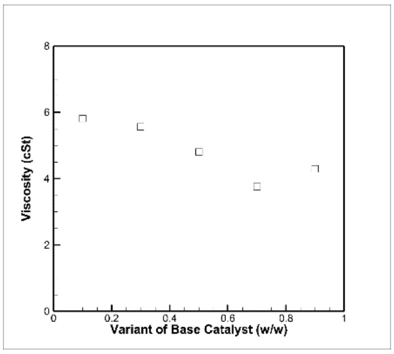


Fig. 4 : Influence of base catalyst variation on kinematic viscosity

It is explained in Fig. 4 that the kinematic viscosity of methyl esters towards increasing base catalyst tends to decrease. The decrease in viscosity is proportional to the increase in concentration of the base catalyst used. Based on experimental results, the kinematic viscosity value of methyl ester shows that the alkaline catalyst reaction succeeded in reducing the viscosity of the catalyst. Factors that influence the kinematic viscosity of methyl esters are the concentration of basic catalysts and the purification process. Kinematic viscosity equation is a comparison between dynamic viscosity and density. From this equation it is known that kinematic viscosity is inversely proportional to density, where density is directly proportional to the concentration of the catalyst base. Then the kinematic viscosity relationship is inversely proportional to the increase in base catalyst concentration.

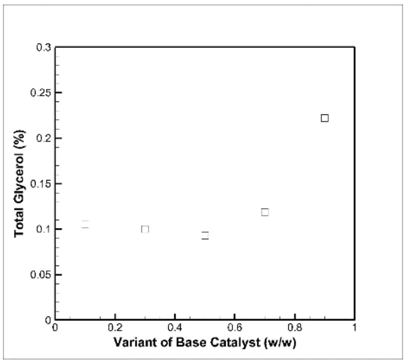


Fig. 5 : Influence of base catalyst variation on total glycerol

Glycerol is a byproduct of methyl esters. The total glycerol in this calculation is the glycerol methyl ester level. Glycerol is a viscous liquid, easily dissolves in water, and binds to water.

From fig.5 the glycerol content tends to increase with increasing base catalyst concentration. The volume of catalyst titration becomes the main parameter in determining the quality of methyl esters. Due to the low volume of the titration the activation energy is low. Based on the Arrhenius law where the activation energy is inversely proportional to the reaction rate constant and the reaction rate constant is directly proportional to the reaction rate. The catalyst is a substance to reduce the activation energy so that with a large catalyst concentration will decrease the activation energy and increase the reaction rate.

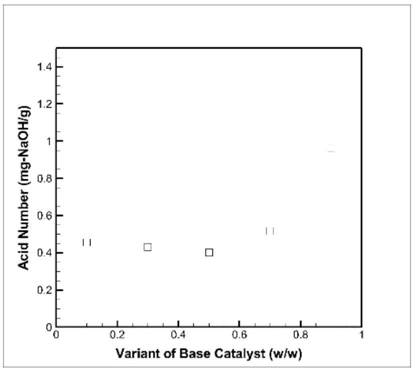


Fig. 6 : Influence of base catalyst variation on acid number

Acid number is the number of milligrams of catalyst needed to neutralize 1 gram of sample (methyl ester). Acid numbers are required to be as small as possible because free fatty acids are corrosive so as to cause damage to the components of diesel engines, high acid numbers can cause fuel deposits, causing pumps and filters more quickly damaged. Acid numbers indicate the acid content still present in methyl esters. Factors affecting numbers are quality of used cooking oil and base catalyst concentration. With a low acid content, the quality of methyl esters increases. This is in accordance with Arrhenius's law where the low activation energy facilitates the rate of reaction, so that the reaction of methyl ester changes will be faster and easier.

Table 2. Biodiesel Physical Properties Testing

Parameter	Waste Cooking Oil	0,1% w/w	0,3% w/w	0,5% w/w	0,7% w/w	0,9% w/w
Density (kg/m^3)	928,7	855,8	858,7	863,3	865,0	**869,3**
Kinematic Viscosity (cSt)	10,55	4,80	5,18	5,51	5,55	**5,54**
Total Glycerol (%)	-	0,046	0,046	0,043	0,043	**0,043**
Acid Number (mg-NaOH/gr)	**1,891**	**0,565**	**0,423**	**0,413**	**0,412**	**0,363**

Fig. 7: Methyl Ester and Waste Cooking Oil

4. Equation

Here are the equations used in working on the production of biodiesel.

$$\boldsymbol{FFA\ levels} = \frac{\boldsymbol{N\ NaOH\ x\ v\ NaOH\ x\ 200}}{\boldsymbol{w\ x\ 1000}}\ \boldsymbol{x\ 100\%} \quad (1)$$

$$\rho = \frac{m}{v} \quad (2)$$

$$\boldsymbol{\mu} = \frac{\rho\ x\ t\ x\ \mu_0}{\rho_0\ x\ t_0} \quad (3)$$

$$v = \frac{\mu}{\rho} \quad (4)$$

$$glycerol = \frac{N\ NaOH\ x\ v\ NaOH\ x\ 92}{w\ x\ 1000}\ x\ 100\% \quad (5)$$

$$Acid\ number = \frac{39{,}9\ x\ v\ NaOH\ \ x\ N\ NaOH}{w} \quad (6)$$

where:

- FFA levels is free fatty acid of used cooking oil,
- N_{NaOH} is normality of NaOH,
- v_{NaOH} is titration volumes from NaOH,
- w is sample mass
- ρ is the density value,
- m is biodiesel sample mass,
- v is biodiesel sample volume,
- μ is the dinamic viscosity value,
- t is the sample time passes through fluid,
- μ_0 is reference of viscosity,

- ρ_0 is reference of density,
- t_0 is reference of sample time passes through fluid
- v is kinematic viscosity value,
- 92 is mass glycerol molarity, and
- 39,9 is mass fatty acid molarity.

5. Conclusion

Based on the analysis of the production of biodiesel pilot Plant method with a variation of alkaline catalyst can be concluded as follows: (i) Production of methyl ester pilot Plant method successfully carried out using transesterification reaction; (ii) by increasing the concentration of base catalysts on biodiesel production The pilot Plant method is known that the biodiesel quality is in accordance with SNI Biodiesel.

6. Nomenclature

N	Normality	N
v	titration volumes	mL
w	sample mass	gram
$\boldsymbol{\rho}$	density value	gram/mL
m	biodiesel sample mass	gram
v	biodiesel sample volume	mL
μ	dynamic viscosity value	cp
t	the sample time passes through fluid	second
μ_0	reference of viscosity	cp
ρ_0	reference of density	gram/mL
t_0	reference of sample time passes through fluid	second
v	kinematic viscosity value	cp

7. Acknowledgments

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8. References

Atmaja, S, 2010. Biodiesel Dari Minyak Jelantah (Waste Cooking Oil) Sebagai Solusi Sumber Energi Alternatif Ramah Lingkungan. Karya Ilmiah Teknologi Bandung.

Budiman, A, 2014. Biodiesel Bahan Baku, Proses, dan Teknologi. Yogyakarta: Erlangga.

Laila, L., Liatiana, O, 2017. Experiment Study Of Total Acid Number And Viscosity Of Palm Oil Based Biodiesel From PT Smart Tbk. Jurnal Teknologi Proses Dan Inovasi Industri, Vol. 2, No. 1.

Eryilmaz, T, 2015. Design Of A Small Scale Pilot Plant Biodiesel Production Plant And Determination Of The Fuel Properties Of Biodiesel Produced With This Plant. Turkish Journal of Agriculture - Food Science and Technology, 3(2): 67-70.

Oseni, M. I., Tuleun, M. T., & Musa, A. Development and Performance Evaluation of a Small Scale Biodiesel Production Pilot Plant. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 4(4): 679-685.

Yulianingtyas, P. Kajian Proses Produksi Biodiesel Melalui Transesterifikasi In Situ Jarak Pagar (Jatropha Curcas L.) pada Skala Pilot Plant. Institut Pertanian Bogor.