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MANUFACTURING BIODIESEL FROM COOKING OIL TEACHING FACTORY PRODUCTS USING BENTONITE CATALYST WITH NON-ALCOHOL ROUTE METHOD

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ABSTRACT

This research investigates an eco-friendly approach to biodiesel production through non-alcoholic pathways using heterogeneous catalysts. The study examines various ratios of methyl acetate to cooking oil and temperatures, revealing that the optimal conditions for biodiesel production are a 1:4 ratio, utilizing a bentonite catalyst (0.75 g), operating at 60°C for 120 minutes. Fourier Transform Infrared Spectroscopy (FTIR) analysis confirms the presence of ester groups, the primary component of biodiesel. Most biodiesel characteristics align with quality standards, including density (0.8844 kg/m3), cetane number (61.9), and acid number. However, the biodiesel flash point falls below the minimum standard, suggesting a potential area for improvement. This research underscores the potential of using methyl acetate as a heterogeneous catalyst for biodiesel production, with most biodiesel characteristics meeting established quality standards, although further work may be needed to address the flash point issue.

Keywords: biodiesel, bentonite, heterogeneous, interesterification, methyl acetate

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INTRODUCTION

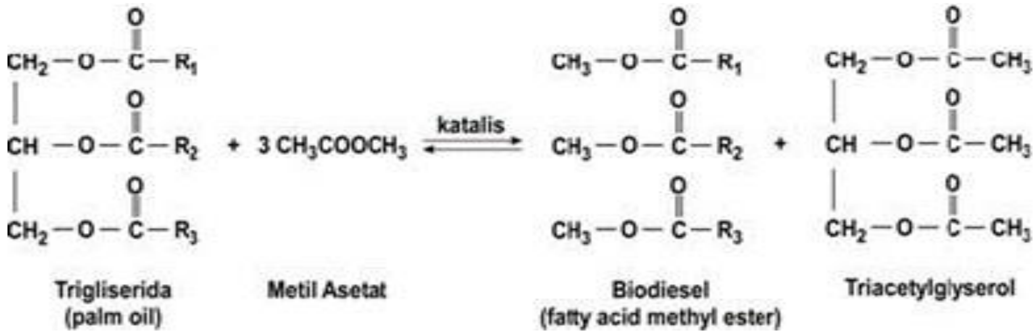
The use of fossil fuels is increasing from year to year. Without alternative energy sources, petroleum reserves are estimated to only be sufficient for another 30-50 years. According to Bappenas (2018), Indonesia's population in 2019 is projected to reach 266.91 million people, consisting of 134 million men and 132.89 million women. This number has increased compared to 2018 with a population of 265 million people [1]. This increase has an impact on the use of energy sources in Indonesia. This is because the high population in Indonesia also influences the increase in the number of vehicles to support the distribution of goods (products) and services to various cities and remote areas.

One alternative that has great potential to be developed in response to the energy crisis is the use of biodiesel produced from biological raw materials. Biodiesel is a renewable alternative fuel produced from vegetable oils, one of which is palm oil, which is commonly known as cooking oil. So far, palm oil has been widely used for cooking oil. For this reason, it is necessary to carry out research efforts to find ways to utilize palm oil into a product that can provide more benefits for human life. One research that is being developed is to produce methyl esters from CPO through the transesterification reaction of vegetable oils (triglycerides) with methanol [2,3].

Making biodiesel which is carried out by transesterification with methanol as a reactant and a base catalyst has many weaknesses, including the saponification reaction and it is difficult to separate because the catalyst is homogeneous. The use of biocatalysts in an alcoholic environment using the transesterification process causes the biocatalyst to be deactivated quickly and its stability will be poor. The catalyst commonly used is a homogeneous catalyst, but this type of catalyst has difficulties during the process of separating and purifying biodiesel from the product. In addition, homogeneous catalysts cannot be reused and can pollute the environment. Based on these problems, it is necessary to develop research on making biodiesel using heterogeneous catalysts. Heterogeneous catalysts have high activity, mild reaction conditions, relatively cheap, non-corrosive, environmentally friendly, and can be separated from the product so it can be reused [4,5]. So the biodiesel synthetic process with an interesterification process via a non-alcohol route is able to make alternative raw materials apart from being easy to obtain and has its own benefits in terms of the biodiesel that will be produced and the catalysts used in the interesterification reaction of this biodiesel are Methyl acetate and Bentonite because not only are the prices affordable However, Methyl acetate and Bentonite are environmentally friendly, non-toxic and produce a by-product, namely triacetylglycerol, which has a higher selling value.

This research aims to synthesize and characterize Biodiesel with a bentonite catalyst with varying rates of methyl acetate and cooking oil using the non-alcohol route method. The SNI 7128:2015 standard is used as a standard for characterization of the biodiesel produced and FTIR is used to see the biodiesel functional groups.

Interesterificationi



Picture 1. Interesterification reaction of vegetable oil via a non-alcoholic reaction route

The interesterification reaction is a method for changing the structure and composition of oils and fats through exchanging acyl radical groups between triglycerides and alcoholic acids (alcoholysis), fats (acidolysis), or esters (transesterification). Interesterification does not affect the degree of saturation of fatty acids or cause isomerization of fatty acids that have double bonds. So, the interesterification reaction will not change the properties of the fatty acids, but will change the profile of fats and oils because they have a different composition from the initial triglycerides. In the interesterification of triglycerides, acyl acceptors such as methyl acetate can be used. The interesterification reaction of triglycerides with methyl acetate produces triacetylglycerol and methyl ester fatty acids.

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Biodiesel Quality Standards

PARAMETER	Satuan	Nilai
Massa jenis pada 40⁰C	kg/m³	850 – 890
Viskositas kinematik pada 40⁰C	mm²/s (cSt)	2,3 - 6,0
Angka setana	Min	51
Titik nyala (mangkok tertutup)	⁰C, min	100
Titik kabut	⁰C, maks	18
Korosi lempeng tembaga (3 jam pada 50⁰C)		nomor 1
Residu karbon - dalam contoh asli - dalam 10% ampas distilasi	%-massa, maks	0,05 0,3
Air dan sedimen	%-vol, maks	0,05
Temperatur distilasi 90%	⁰C, maks	360
Abu tersulfatkan	%-massa, maks	0,02
Belerang	(mg/kg), maks	100
Fosfor	(mg/kg), maks	10
Angka asam	mg-KOH/g, maks	0,5
Gliserol bebas	%-massa, maks	0,02
Gliserol total	%-massa, maks	0,24
Kadar ester metal	%-massa, min	96,5
Angka iodium	%-massa (g-I2/100g), maks	115
Kadar monogliserida	%-massa, maks	0,8
Kestabilan oksidasi - Periode induksi metode rancimat, atau - Periode induksi metode petro oksi	Menit	360 27

(Sumber: SNI 04-7182: 2015)

METHOD

This applied research was carried out at the Process Unit and Teaching Factory Laboratory (TeFa) in the Chemical Engineering Department of the Lhokseumawe State Polytechnic. Cooking oil resulting from processing CPO (crude palm oil) from the Teaching Factory which consists of the bleaching and degumming stages, filter stage, deodorization stage and crystallization stage, as well as fractionation in the vegetable oil processing process is used as raw material for making biodiesel in this research.

Prepare 150 ml of cooking oil from the teaching factory and 0.75 grams of bentonite. Put the cooking oil and bentonite into a three-neck flask equipped with a stirrer, thermometer and condenser. Install the three-neck flask on the support and connect the condenser to the cold water source. Turn on the magnetic stirrer and set the stirring speed according to the desired speed. Heat the reaction mixture using a water bath until it reaches the desired reaction temperature. Add a certain amount of methyl acetate according to the desired mole ratio. Add a base catalyst, namely potassium hydroxide (KOH) with a weight ratio of catalyst to cooking oil of 0.5%. Allow the reaction mixture to react for the desired reaction time. Turn off the water bath and wait until the reaction mixture reaches room temperature. Separate the reaction product into two layers using a separating funnel. The top layer is biodiesel and the bottom layer is triacetin. Store biodiesel in closed containers to prevent oxidation.

RESULTS AND DISCUSSION

The results of this study indicate that the ratio of cooking oil to methyl acetate affects the characteristics of biodiesel produced from the interesterification reaction. The optimal ratio of cooking oil to methyl acetate is 1:4, as seen in table 4.1. The optimal ratio of cooking oil to methyl acetate is 1:4 because in this ratio there is an equilibrium between the amount of triglycerides and methyl acetate which react to form esters. If the ratio of cooking oil to methyl acetate is too low, then the amount of triglycerides that react to form esters will be less, so the yield of biodiesel product characteristics will be low. If the ratio of cooking oil to methyl acetate is too high, then the excess amount of methyl acetate will interfere with the interesterification reaction, so that the biodiesel characteristics will also be low. The results of this research also show that 0.75 grams of bentonite catalyst and a reaction temperature of 60°C for 2 hours are the optimal reaction conditions to produce biodiesel from cooking oil with methyl acetate.

The bentonite catalyst functions as a substance that accelerates the interesterification reaction between triglycerides and methyl acetate and also as an absorbent for the water content contained in the oil. A reaction temperature of 60°C is a temperature high enough to increase the reaction rate without causing damage to the ester. A reaction time of 2 hours is long enough to reach reaction equilibrium without causing side reactions. The results of this research have positive implications for the development of biodiesel as an environmentally friendly alternative fuel. Biodiesel produced from cooking oil with methyl acetate has a high ester content, so it has a high calorific value and low exhaust emissions.

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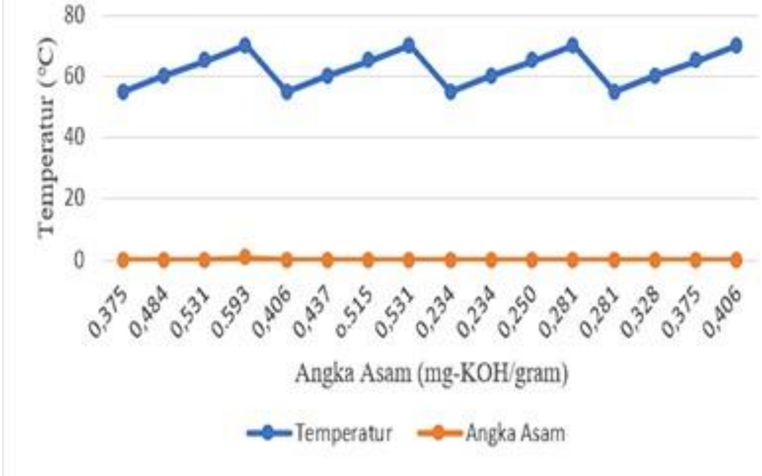
1. Biodisel acid number levels



Picture 1. Effect of temperature on the acid number of biodiesel

Biodiesel from cooking oil with a maximum limit of 0.4 mg-KOH/g acid value according to Decree of the Director General of EBTKE No. 189.K/10/DJE/2019, the SNI 04-7182-2015 standard has a limit of 0.8 mg-KOH/g. The acid number is an indicator of the acid level in vegetable oils and can cause operational and stability problems in biodiesel if the content is too high. With a maximum limit of 0.4 mg-KOH/g acid value, biodiesel from palm oil has good stability and tends not to cause problems in vehicle engine fuel systems. Maintaining the quality of biodiesel also helps reduce the risk of soap deposits forming when biodiesel is mixed with water.

In Picture 2 it can be seen that the increase in temperature greatly influences the value of the acid value obtained, that the higher the temperature, the higher the acid number produced. The best data shows an acid content of 0.234 mg-KOH/g in palm oil-based biodiesel, indicating that the biodiesel complies with the limits set by the standards that have been set. With an acid content below the limit of 0.4 mg-KOH/g, this biodiesel is considered high quality and suitable for use as an environmentally friendly alternative fuel. Improved biodiesel quality provides many benefits, such as increased engine performance and durability, as well as reduced environmental impact through reduce greenhouse gas and pollutant emissions.

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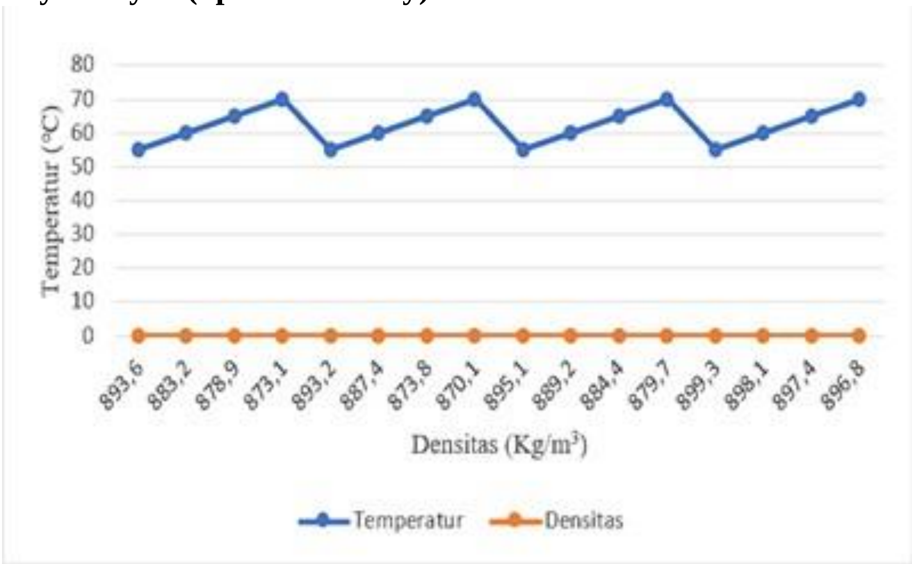
2. Density Analysis (Specific Gravity)



Picture 2. Effect of Temperature on Biodiesel Density

Density measurements are carried out to determine the ratio of mass to a certain volume of biodiesel obtained using a pycnometer. It can be seen in the graph above that the lowest density value is 870.1 kg/m3 at a temperature of 70°C. This shows that the higher the temperature of the interesterification process, the lower the resulting density value. When compared with the density value from SNI 04-7182-2015 and Decree of the Director General of EBTKE No. 189.K/10/DJE/2019, overall the density values in this study have met the standards.

In making biodiesel through the interesterification process, the density value that meets the standards has a very big influence. Biodiesel density that meets standards indicates good quality and appropriate chemical composition. Additionally, proper density also contributes to engine performance by ensuring smooth flow and optimal combustion. It can be seen in Figure 3 from the graph above that the higher the temperature of the interesterification process, the lower the resulting density value, namely 870.1 kg/m3 at a temperature of 70°C. In addition, meeting density standards is also important to ensure that biodiesel meets the requirements and specifications set by industry standards and government regulations. By controlling operating conditions, a biodiesel density that meets standards can be achieved.

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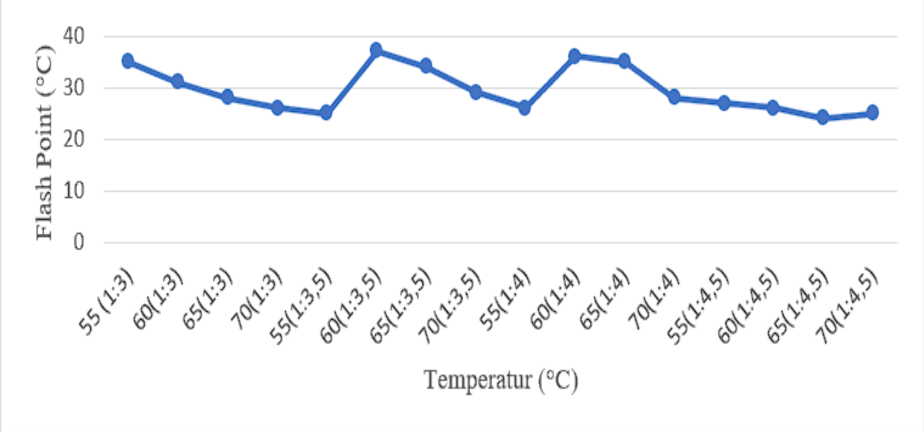
3. Flash Point Analysis (Flash Point)



Picture 3. Effect of Interesterification Temperature on Biodiesel Flash point

The lowest temperature at which biodiesel can produce flammable vapors when an ignition source is present is called the flash point of biodiesel. According to the Decree of the Directorate General of EBTKE NO. 189.K/10/DJE/2019 the minimum flash point that must be met by biodiesel to be considered safe and suitable for use as fuel is a minimum of 130 °C and for the SNI standard 04-7182-2015 the minimum flash point is 100 °C. As can be seen from Figure 4 in the graph above, with every increase in temperature the flash point value decreases, so this indicator shows that the higher the temperature of the interesterification process, the lower the resulting flash point value. In this case the data obtained shows an average biodiesel flash point of 26 °C, which is far below the established standards which require a minimum of 130 °C and 100 °C.

Data that does not meet these standards indicates a higher potential risk of fire when biodiesel is used as fuel. In this case, biodiesel with a low flash point can be more flammable and cause serious harm, especially in environments that have potential exposure to heat or ignition sources. This difference can be caused by the quality and composition of the raw materials used in the biodiesel manufacturing process. Several factors that can influence a low flash point include a high water content or compounds related to non-ester components such as water, free fatty acids, or other polar compounds. These contaminants can lower the flash point of biodiesel and make it not meet established standards.

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4. Satana Number Analysis

Picture 4. Effect of temperature on cetane number

In achieving biodiesel cetane numbers that meet SNI standards 04-7182-2015 and DIRJEN EBTKE Decree NO. 189.K/10/DJE/2019, there are several factors that can influence the final results. The quality of the raw materials used, such as high quality vegetable oil, has an important role in achieving biodiesel cetane numbers that meet standards. Apart from that, a good production process also plays a significant role. Controlling temperature, reaction time, and using appropriate catalysts are important steps that must be considered in the biodiesel production process.

The cetane number of biodiesel is an important parameter used to evaluate the quality and performance of biodiesel. In this case, the biodiesel cetane number data of 61.9 indicates that the biodiesel meets the established standards which set a minimum cetane number of 51. In Figure 5 from the graph above it can be concluded that with every increase in temperature the value of the cetane number decreases, so this indicator shows that the higher the temperature of the interesterification process, the lower the cetane number produced. A high cetane number indicates success in the biodiesel production process with an appropriate chemical composition and optimal interesterification reaction. With biodiesel that meets state standards

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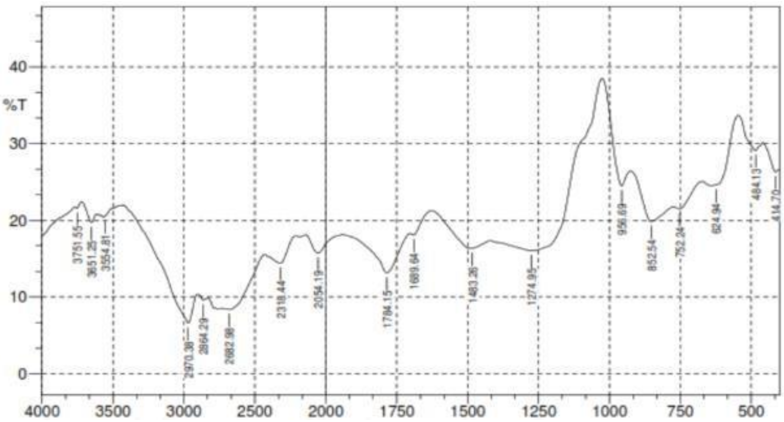
5. FTIR Test



Picture 5. FTIR analysis of Biodiesel

In Picture 6 of the graph above you can see the typical peaks for biodiesel. The peak at wave number 3554.81 cm-1 indicates the presence of hydroxyl groups (O=H) which come from water, methyl acetate and bentonite. The absorption peaks in the wave number area of 3645.46 cm-1 and 3606.89 cm-1 show the –OH group bonded to cations on the octahedral sheet and the bond between the –OH group and Al+3 cations (Caccamo et al., 2020). The peak at wave number 1784.15 cm-1 indicates the presence of an ester group (CO=O) which is the main component of biodiesel. This ester group is formed from the reaction between fatty acids and methyl acetate. The peak at wave number 2054.19 cm-1 indicates the presence of an alkene group (C=C) which is a minor component of biodiesel. This alkene group comes from unsaturated fatty acids found in cooking oil. The peak at wave number 752.24 cm-1 indicates the presence of an alkane group (CH) which is a minor component of biodiesel. This alkane group comes from saturated fatty acids found in cooking oil.

You can also see that biodiesel has a peak at wave number 956.69 cm-1 (C=CH) which indicates the presence of double bonds in the carbon chain. This means that the cooking oil used as raw material for biodiesel contains unsaturated fatty acids, such as oleic acid or linoleic acid.

CONCLUSION

The data shows that with each increase in temperature the density value, flash point, cetane number decreases, so this indicator shows that the higher the temperature of the interesterification process, the lower the resulting value. Meanwhile, for the acid number, the higher the temperature, the lower the value will be. The influence of the ratio of cooking oil to methyl acetate on the characteristics of biodiesel produced from the interesterification reaction. Shows that the optimal ratio is 1:4, with reaction conditions using 0.75 gr bentonite catalyst, temperature 60°C, and time 120 minutes. The biodiesel produced has characteristics that meet SNI 7128:2015 standards. As for the flash point, the results found were below the minimum standards set. FTIR results can be seen typical peaks for biodiesel, such as the wave numbers 1784.15 cm-1 (CO=O), 752.24 cm-1 (CH), 3554.81 cm-1(O=H), 2054.19 cm-1 (C=C) and 956.69 (C=CH). These peaks indicate the presence of ester groups which are the main component of biodiesel so it can be concluded that the use of bentonite catalyst has succeeded in converting fatty acids into biodiesel.

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