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Biodiesel Characterization Study from Castor Oil (Jatropha Curcas L) with CaO/K_2O Catalyst

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ABSTRACT

Biodiesel is still being developed as a renewable fuel to replace a diesel fuel. Biodiesel production of castor oil has high potential because the oil did not compete with foods. Furthermore, a transesterification process can be optimized by heterogeneous base catalysts. Thus, this study aims to: (1) synthesize CaO/K_2O catalysts to be used in the transesterification process, (2) synthesize biodiesel of castor oil and characterize it according to SNI 7182:2015, and (3) study the effect of CaO/K_2O variations on biodiesel product. This laboratory experimental research was carried out in the following stages: (1) characterization of castor oil, (2) esterification, (3) preparation of CaO/K_2O catalyst, (4) transesterification, and (5) characterization of the synthesized methyl ester. The results showed that the characterization of castor oil included a density of 1.074 g/mL, an acid number of 9.5 mg/g, a free fatty acid (FFA) of 5.09%, and a viscosity of 701 cSt. Stratified esterification and transesterification showed a significant effect on reducing FFA, so the characterization of the transesterified methyl ester from the best catalyst variations (CaO/K_2O 1:2) included a density of 1.016 g/mL, an acid number of 1.1 mg/g, FFA content of 0.58%, moisture content of 1.1%, viscosity 43.55 cSt, and refractive index (25°C) of 1.466.

Keywords: *biodiesel; castor oil; characterization; metal oxide*

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ABSTRACT

Biodiesel masih dikembangkan sebagai bahan bakar terbarukan pengganti diesel. Produksi biodiesel dari minyak jarak berpotensi tinggi karena minyak tidak berkompentisi dengan bahan-bahan pangan. Selanjutnya, proses transesterifikasi dapat dioptimasi oleh katalis basa heterogen. Maka, penelitian ini bertujuan untuk: (1) mensintesis katalis CaO/K_2O yang akan digunakan dalam proses transesterifikasi, (2) mensintesis biodiesel dari minyak jarak dan karakterisasi sesuai SNI 7182:2015, dan (3) mempelajari pengaruh variasi CaO/K_2O terhadap produk biodiesel. Penelitian eksperimen laboratoris ini dilakukan dengan tahapan: (1) karakterisasi minyak jarak, (2) esterifikasi, (3) preparasi katalis CaO/K_2O, (4) transesterifikasi, dan (5) karakterisasi metil ester hasil sintesis. Hasil penelitian menunjukkan bahwa karakterisasi Minyak Jarak meliputi massa jenis 1,074 g/mL, angka asam 9,5 mg/g, kadar asam lemak bebas (ALB) 5,09%, dan viskositas 701 cSt. Esterifikasi bertingkat dan transesterifikasi menunjukkan efek penurunan ALB yang signifikan, sehingga karakterisasi metil ester hasil transesterifikasi dari pengaruh variasi katalis terbaik (CaO/K_2O 1:2) meliputi massa jenis 1,016 g/mL, Angka asam 1,1 mg/g, kadar ALB 0,58%, kadar air 1,1%, viskositas 43,55 cSt, dan indeks bias (25°C) 1,466.

Kata Kunci: *Biodiesel; minyak jarak; karakterisasi; oksida logam*

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INTRODUCTION

Diesel fuel policies continue to change the conventional fuel. The government committed to provide sufficient energy needs, but crude oil prices continue to decline from year to year [1]. A wise alternative for reducing carbon gas emissions and the greenhouse effect is the use of renewable fuels, especially from biomass leaved competition of foods [2]. Of course in Indonesia, the government has encouraged the production of renewable fuels, such as biodiesel, and bio-fuel [3]. Biodiesel is also known as biofuel synthesized from vegetable oils and/or animal oils, such as palm, coconut, candlenut, jatropha, *Calophyllum inophyllum*, *Ceiba pentandra*, peanuts, fish oil and cow oil wastes. As observed, biodiesel has advantages over petrodiesel, namely: reducing carbon monoxide and SO_2 emissions, safe in storage and transportation because it does not contain toxins, it does not require high technology in its manufacture, and its waste (glycerin) can be used as a basic material for making soap [4].

The availability of oil is important as a raw material for biodiesel and the optimal synthesis has been the focus of many studies to date [5]. Biodiesel synthesis is commonly carried out *via* the alcoholysis process [6], namely the reaction between oil and alcohol assisted by a catalyst. The alcoholysis process is also referred to as a transesterification reaction [7], which proceeds from the transesterification reaction of vegetable oil assisted by a base catalyst. However, the high FFA content of oil should be treated *via* the esterification process [8]. One of the oils with high FFA levels is castor oil from the Jatropha seed which is abundant in Indonesia [9]. For example, the Jatropha seeds yield 4,100 – 6,750 kg/ha/year in the third year in Asembagus, Indonesia [10], and the Jatropha seed has high oil content about 38.7-45.8% [11].

The conditions for the transesterification reaction leave a complicated problem. The reaction conditions to control parameters are reaction temperature, oil and alcohol concentration, type of oil and alcohol used, reaction time, type and concentration of catalyst [12]. In the current trend, the heterogeneous catalyst plays a crucial role in the transesterification process. The previous study, CaO has high catalytic activity (due to high basic strength), low methanol solubility, low-cost, and long-term stability [13]. On the other hand, biodiesel synthesis of castor oil by K_2O catalyst in the optimum conditions can yield biodiesel up to 98.62% [14]. The combinations of calcium oxide and potassium oxide remains a potential study of castor oil conversion to biodiesel. With waste cooking oil, CaO/K_2O can be used as catalyst in the transesterification yielded biodiesel up to 92.37% [15]. So, in this study it observes the effect of calcium oxide and potassium oxide combinations on synthesizing of biodiesel from castor oil. The variation of CaO/K_2O is evaluated to understanding the contribution of the metal oxide in the transesterification process. Therefore, this study aims to: (1) synthesize CaO/K_2O catalysts to be used in the transesterification process, (2) synthesize biodiesel of castor oil and characterize it according to SNI 7182:2015, and (3) study the effect of CaO/K_2O variations on biodiesel product.

LITERATURE REVIEW

Castor oil

Castor oil is an oil extracted from Jatropha seeds which is widely grown in people's homes and plantations. The Jatropha plant is a shrub with a height ranging from 1 to 7 meters, with irregular branches. The Jatropha plant grows on marginal and arid land at 0 - 500 m above sea level, and tolerates drought conditions [16]. The stems are woody, cylindrical in shape, and can emit sap. This plant is a type of plant that grows widely in tropical and subtropical areas. It has the ability to survive in dry areas and critical land, and its non-edible oil content is around 35% [17].

Biodiesel

Biodiesel can be used directly in vehicles and diesel engines without further modification. Diesel engines that used biodiesel produce lower carbon monoxide emissions, unburned hydrocarbons, particulates and toxic air compared to diesel engines that used petroleum fuel, so biodiesel can reduce the effect of global warming. The two reactions applied in biodiesel synthesis are esterification and transesterification, both reactions have certain requirements to be carried out during production, where oil that has a Free Fatty Acid (FFA) content of $\geq 2\%$ is required to undergo an esterification reaction to reduce its FFA content , while oil with FFA content ≤ 2% can be directly transesterified to convert triglycerides into methyl esters (biodiesel) [18].

METHODS

This study was conducted on a laboratory scale. There were 5 main stages, namely: (1) characterization of castor oil samples including density, free fatty acids (FFA), acid number and viscosity, (2) esterification of castor oil if the FFA content was more than 5%, (3) synthesis of CaO/K_2O catalyst (4) synthesis of biodiesel through the transesterification process in castor oil, (5) characterization of the resulting product including acid number, viscosity, water content, refractive index and density.

The tools were reflux, stative, clamp, water hose, Beaker glass, Erlenmeyer (250 mL), stir glass, spatula, digital balance, Petri dish, test tube, pipette, thermometer, vial, Oswald viscometer, burette, separating funnel, measuring cup, watch glass, three-neck flask, volumetric flask (100 mL), pycnometer, glass bottle, cup and volume pipette, hose, aluminum foil, label paper, stopwatch, universal indicator paper, pestle, mortar, clamps, stative, filler , heating mantle, hot plate, furnace, oven, spray bottle, and Abbe refractometer. Meanwhile, the materials were distilled water, H_2SO_4 (p.a., Sigma Aldrich), KOH (p.a., Sigma Aldrich), phenolphthalein indicator, methanol (p.a., Sigma Aldrich), CaO (p.a., Sigma Aldrich), oxalic acid (p.a., Sigma Aldrich), and castor oil.

Characterizations of Castor Oil

a) Density

The initial step in determining the density value was carried out by weighing the empty pycnometer and recording the weight. The sample was then added until full, weighed and recorded. This test was carried out twice. The density can be determined using the following equation.

$$\rho\left(\frac{\text{g}}{\text{ml}}\right) = \frac{\text{Mass of methyl ester (g)}}{\text{Volume of methyl ester (ml)}} \quad \ldots\ldots (1)$$

b) Free Fatty Acid (FFA)

Castor oil (1 gram) was put into a clean Erlenmeyer which had been weighed. 10 mL of alcohol solvent was added. After that, 3 drops of phenolphthalein indicator were added and titrated with 0.1 N KOH solution until the solution turned pink. The amount of KOH used for titration was recorded. This FFA was carried out twice and determined using the following equation.

$$\text{FFA} = \frac{N_{KOH} \times V_{KOH} \times BM_{sample}}{m_{sample} \times 1000} \times 100\% \quad \ldots\ldots (2)$$

Note: N = normality of KOH (N), V = volume of KOH (mL), m_{sample} = weight of the substance being tested (g), BM_{sample} = molecular weight of the substance being tested.

c) Acid Number

Castor oil sample (±1 g) was put into an Erlenmeyer. Then 10 mL of methanol was added to the Erlenmeyer. This solution was then added with 3 drops of phenolphthalein indicator and titrated using 0.1 N KOH solution until the color changed from colorless to pink color. This test was carried out twice. The equation for determining the acid number is as follows.

$$\text{Acid Number} = \frac{\text{V x N x BM}}{\text{sample mass}} \quad \ldots\ldots (3)$$

Note: V = volume of KOH, N = normality of KOH, BM = molecular weight of KOH.

d) Viscosity

The viscosity value was determined by inserting distilled water into the Oswald viscometer tube and recording the flow time to pass the distance between the two marks on the viscometer using a stopwatch as a comparison. Then the same treatment was carried out on the sample and the flow time was also recorded. This test was carried out twice. Calculation of kinematic viscosity can be calculated using the following formula:

$$\frac{\eta_1}{\eta_2} = \frac{\rho_1 \text{ x } t_1}{\rho_2 \text{ x } t_2} \quad \text{..... (4)}$$

Note: η1 = viscosity of methyl ester (cSt), η2 = viscosity of distilled water (cSt), ρ1 = density of methyl ester (g/mL), ρ2 = density of distilled water (g/mL), t1 = flow time of methyl ester (s), t2 = distilled water flow time (s).

Esterification of Castor Oil

Reducing free fatty acid levels was carried out by an esterification process using a set of reflux equipment. castor oil (200 g) was put into a three-neck flask and mixed with 1 mL of concentrated H_2SO_4 solution and 15 mL of methanol accompanied by heating to a temperature of 70 ºC. The mixture was then refluxed for 2 hours at 70 ºC. Then 7.5 mL of methanol and 0.5 mL of concentrated H_2SO_4 were added and the reflux process continued for 1 hour. The results are then cooled, put into a separating funnel and allowed to stand until two layers formed. The top layer was a mixture of triglycerides (oil) and fatty acid methyl esters while the bottom layer contained concentrated H_2SO_4 and unreacted methanol. The top layer was separated, then the esterification process was carried out twice again, the top layer resulting from three times esterification was then washed with a little distilled water, and heated on a hot plate at a temperature of ±90 ºC to remove residual water and tested with a universal indicator to determine its acidity properties, so that Castor oil with low fatty acid content was obtained for the transesterification process.

Synthesizing of CaO/K_2O Catalyst

CaO was put into a beaker, then dissolved with 10% alcoholic KOH with a mass and volume ratio between CaO and alcoholic KOH of 1:1, 1:2, and 2:1. The mixture was then heated for 60 minutes while stirring, after that it was evaporated until the solvent runs out, finally the catalyst was heated in a furnace at a temperature of 300 ºC for 90 minutes. On the other hand, alcoholic KOH was prepared by dissolving 10 grams of solid KOH with 100 mL of methanol p.a in a measuring tube.

Transesterification with Reflux Method

The esterified castor oil (20 g) was put into three-neck flask. The oil was heated to a temperature of ±65 ºC. After that, 5 mL of methanol was put into a three-neck flask for each addition of CaO/K_2O with a concentration of 3% w/w oil. Then the transesterification process was carried out by placing the mixture in a reflux equipment for 120 minutes.

Once finished, the results obtained were then put into a separating funnel until two layers formed for 24 hours. The top layer was methyl ester while the bottom layer was glycerol. The top layer was separated and washed with warm water to remove remaining glycerol and catalyst until the results obtained showed a neutral pH. Finally, heating was carried out at a temperature of ±90-100 ºC for 15 minutes to remove the remaining washing water in the methyl ester. The methyl ester obtained was then characterized according to quality standards as biodiesel fuel.

Characterization of The Synthesized Methyl Ester

The characterization in this study included tests for density, acid number, FFA content, viscosity, water content and refractive index. The density, acid number, FFA content and viscosity tests were carried out in accordance with the castor oil characterization procedure in the previous discussion. Next, the water content and refractive index tests were detailed as follows.

a. water content

The water content was determined by placing 3 grams of the sample in a dry cup and knowing the weight. Then the sample and cup were heated in an oven at a temperature of 110 ºC for 3 hours. Then the cup was cooled in a desiccator and weighed, then heated again until a constant weight was obtained. The water content of the sample can be calculated using the formula,

$$\text{water content} = \frac{W-(W1-W2)}{W} \times 100\% \qquad \text{..... (5)}$$

Note: W= Sample weight (gr), W1= Weight of sample+cup after heating (gr), W2= Weight of empty cup (gr)

b. refractive index

Before determining the refractive index, it was necessary to clean the refractometer glass with alcohol. Then the synthesized methyl ester was dropped on the refractometer glass and covered. Reading the refractive index value was observed by setting the light line and dark line at the exact cross position of the observation lens. The temperature and refractive index values were then recorded as data to determine the refractive index value at a temperature of 25 ºC. The refractive index of methyl ester is calculated using the following equation:

$$n = n^{Ti} + 0{,}0004\,(T_i - T) \qquad \text{..... (6)}$$

Note: n = Refractive index at reference temperature, n^{Ti} = Reading results taken at working temperature, Ti = Temperature at the time of working, T = Reference temperature, 0.0004 = Correction factor.

Research Data Collection

Research data was obtained from the characterization stages of castor oil, esterification and transesterification (synthesis) of methyl esters from castor oil using the reflux method, and characterization of the synthesized methyl ester (biodiesel) compounds. The results of identifying methyl ester compounds using the Abba Refractometer instrument produced data on the refractive index of the synthesized methyl ester.

Data analysis method

Data analysis was carried out based on data obtained from the methyl ester synthesis stage. The characterization carried out on the results of this research includes density, acid number, FFA, water content, viscosity and refractive index which are then compared with the SNI for biodiesel, namely SNI 7182:2015. The data was analyzed descriptively.

RESULTS AND DISCUSSION

Characterization of Castor Oil

The castor oil used in this study was castor oil from chemical stores and has been processed into ready-to-use oil that can be used for pharmaceutical purposes and as an additional ingredient in cosmetics. So, the oil used was a clear yellow liquid as in Figure 1.

Figure 1. Castor Oil Sample

Then this oil was initially characterized as a comparison in the characterization of methyl esters resulting from the transesterification reaction. The characterization results are shown in Table 1.

Table 1. Characterization Results of Castor Oil

Character	Density (g/mL)	Acid Number (mg KOH/g oil)	FFA (%)	Viscosity (26 ºC) (cSt)
Castor Oil	1.074	9.5	5.09	701
SNI (01-1904-1990)	0.961 – 0.963	max 2.0	-	-

Based on Table 1, the characterization results show that the density of castor oil is 1.074 g/ml. The density results obtained exceed SNI standards. This shows that the oil contains certain substances such as impurities. The acid value obtained for castor oil was 9.5 mg/g oil, which was almost 5 times greater than SNI standard. This can be said that the quality of the oil is not good. The acid number greatly influences the quality of the oil, the higher the acid number of an oil, the worse the quality of the oil, and vice versa, the lower the acid number, the better the quality of the oil. Next, free fatty acids (FFA) were analyzed using the alkalimetric titration method. The higher the acid number, the higher free fatty acids contained in the oil and the lower the quality of the oil. Based on the research, the FFA content of castor oil was obtained at 5.09%, so an esterification reaction is needed to reduce the FFA content before the oil is synthesized with alcohol in a transesterification reaction. Next, the viscosity of castor oil is calculated using the Poiseuille equation and the use of water as a widely used comparison fluid. The results obtained were that the average kinematic viscosity of castor oil in this study was 701 cSt at 26 ˚C. This is not mentioned in the SNI standard, but shows a high enough value that requires esterification treatment before transesterification is carried out.

Esterification of Castor Oil

The result obtained of the esterification process was a two-layer solution in which the brownish top layer is the methyl ester of the main ingredient in the transesterification reaction, while the colorless bottom layer is the remaining catalyst and alcohol which must be immediately separated to avoid the occurrence of carboxylic acid. This is based on the fact that the esterification reaction is an equilibrium reaction and can be reversed.

Because FFA of castor oil is very high, the top layer was then esterified again twice, resulting in a browner solution due to the temperature being too high. Just like the first process, the bottom layer of the esterification product must be immediately discarded and the top layer washed with warm water to remove remaining catalyst and alcohol that did not participate in the reaction. So the final result of this treatment is triglycerides which are then transesterified with CaO/K_2O catalyst.

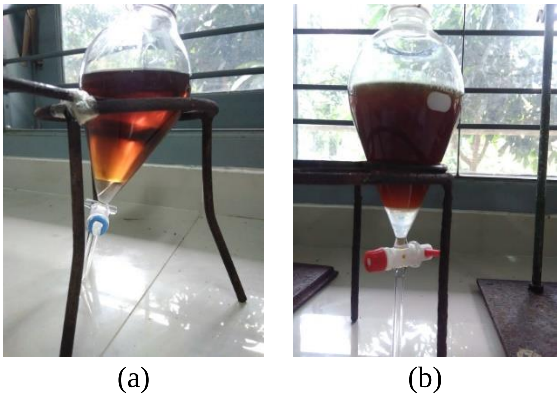

Figure 2. Esterification: first (a) and second (b)

CaO impregnated with alcoholic KOH

The catalyst in this study is a heterogeneous base catalyst that is in solid form so that it can be separated at the end of the synthesis. Even though it has the advantage of being easy to find in nature and affordable, this catalyst easily reacts with air containing water vapor to form $Ca(OH)_2$ and decrease in catalytic activity occurs. To prevent this degradation, a metal is needed that is inserted using a wet impregnation method [19]. In this study, the CaO catalyst used is pure CaO solid to avoid contamination of other compounds in the catalyst. The CaO solid that had been ground was then weighed 3 times, each weighing 5 grams. This was done to simplify the process of impregnation of CaO with KOH dissolved in 96% methanol. This process is carried out to increase the wettability and catalytic activity of CaO. The catalyst produced after the calcination process (as in Figure 3) is cooled in a desiccator. In this study, the catalyst added to the three-neck tube for each reaction was 3% of the weight of the esterified oil sample.

Figure 3. CaO/K_2O calcined with ratio: 1:1 (a), 1:2 (b), dan 2:1 (c)

Methyl Ester Synthesis by Transesterification

Transesterification is the process of exchanging the R″ organic group in an ester with the R′ organic group from alcohol, which is usually called the alcoholysis process. The alcoholysis process is slow and must be catalyzed by a base catalyst in the synthesis of methyl esters in biodiesel production. In this study, the transesterification reaction was carried out using the reflux method for 120 minutes, with heating at a temperature of 65-70 ºC as can be seen in Figure 4.

Figure 4. Transesterification of Castor Oil by Reflux Method

20 grams of the esterified triglyceride was put into a three-neck flask, then heated and added with a CaO/K_2O catalyst of 3% by weight of oil and methanol with oil:methanol molar ratio of 1:6. This comparison was made based on the stoichiometry of the transesterification reaction [20].

The results of the transesterification with CaO/K_2O catalysts (1:1, 1:2, and 2:1 variations) are a mixture of two layers where in the bottom layer there are impurities originating from the calcium catalyst used. The bottom layer was removed while the yellowish-brown top layer was washed with warm water and then characterized for comparison with castor oil. Meanwhile, the top layer was a biodiesel product (methyl ester). The methyl ester product is shown in Figure 5.

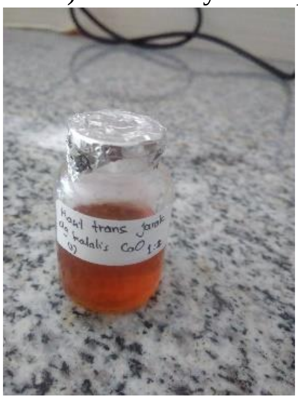

Figure 5. Biodiesel (Methyl Ester) of Castor Oil

Characterization of Methyl Ester

1) Density

Density shows the substances's amount (ratio) in a unit volume. Density is influenced by the composition of fatty acids and their purity. According to SNI 2015, biodiesel density is in the range of 0.850-0.890 g/mL, which is measured at a temperature of 40 ºC. The average density of methyl ester produced from castor oil in this study (Table 2) was 1.0 g/ml calculated at a temperature of 26 ºC so it cannot be ascertained whether this methyl ester meets the 2015 SNI standards.

Table 2. Characterization of Density of the Methyl Ester

CaO/K_2O with ratio:	average density (g/ml)
1:1	1.058
1:2	1.016
2:1	1.035

Even though it has not been shown that the use of the CaO/K_2O catalyst can fulfill SNI 7182:2015, it can be concluded that this catalyst can be used to synthesize triglycerides into methyl esters because of the decrease in the density value from 1.074 g/ml to 1.058; 1.016; 1.035 g/ml. The largest change in density is when using a CaO/K_2O catalyst with a ratio of 1:2.

2) Acid Number

The acid number is the number of milligrams of KOH needed to neutralize the free fatty acids contained in 1 gram of oil or fat. The higher the acid number, the lower the oil quality [21]. The acid number is an indicator of biodiesel quality, a high value indicates damage or decline in the quality of biodiesel due to oxidation. The synthetic methyl ester acid numbers can be seen in Table 3.

Table 3. Characterization of Acid Number of The Methyl Ester

CaO/K_2O with ratio	Acid number (mg/g)
1:1	1.68
1:2	1.1
2:1	1.56

Table 3 shows that the acid number obtained from the synthesis with the three catalysts does not meet SNI 7182:2015 which is 0.5 mg/g methyl ester, but the acid number using the CaO/K_2O catalyst (1:2) is close to 0.5 mg/g as written in SNI 7282:2015, it may be necessary to carry out multilevel transesterification or increase the amount of CaO/K_2O and methanol to excess.

3) Free Fatty Acid

The volume of KOH is recorded for each titration result of methyl ester synthesis at three different catalyst, then the average FFA is calculated and compared with the biodiesel FFA in SNI 7182:2015 (Table 4).

Table 4. Characterization of FFA of The Methyl Ester

CaO/K_2O with ratio	Average FFA (%)
1:1	0.89
1:2	0.58
2:1	0.82

The FFA standard written in SNI 7182:2015 for biodiesel must not exceed 0.5%, while the synthetic FFA data exceeds SNI, so the methyl ester cannot be used as biodiesel. However, it is possible that during esterification many esters are not formed from castor oil triglycerides, and in other experiments excess alcohol and an additional amount of acid catalyst can be used. Even so, this synthesis was successful because the FFA of castor oil fell drastically from 5.09% to 0.89%, 0.58% and 0.82%.

4) Water Content

Water content is calculated from the difference between the weight of the oil before the water in the oil is evaporated and the weight of the oil after the water in the oil is evaporated. The method most widely used to find water content is heating, where a sample of known weight is then heated in an oven at a certain temperature for several hours, then the sample is cooled in a desiccator to absorb the remaining water vapor. This is carried out several times until a constant weight of the heated oil is obtained. Table 5 is the water content data for each synthesis result.

Table 5. Characterization of Water Content of The Methyl Ester

CaO/K_2O	Methyl ester mass before heating	methyl ester mass after heating	Water content (%)
1:1	3.037	3	1.2
1:2	3.055	3.021	1.1
2:1	3.010	2.914	3.1

In SNI 7182:2015, the maximum permitted water content is 0.05%, so the water content obtained from the research is not in accordance with SNI. This is a result of several factors, one of them is that the temperature used to heat the oil is not high enough, or the time used to heat the methyl ester is not long enough so that all the mixed water has not evaporated.

5) Viscosity

Viscosity is one of the main parameters in determining the quality of methyl ester, because it has a big influence on the effectiveness of methyl ester as a fuel. A viscosity value that is too high makes it difficult for the methyl ester to flow because the forces between the molecules become stronger, which will cause damage to the engine. High viscosity values are usually influenced by the molecular weight of the solute in the liquid. The higher the molecular weight, the greater the viscosity. The viscosity results were shown in Table 6.

Table 6. Characterization of Viscosity of The Methyl Ester

CaO/K_2O with ratio	Viscosity (cSt) on 26 ºC
1:1	103.5
1:2	43.55
2:1	62

If based on SNI 7182:2015, the biodiesel viscosity standard is only around 2.3-6.0 cSt with measurements at a temperature of 40 ºC, so it is necessary to test the viscosity of methyl ester at an appropriate temperature to compare with quality standards. The temporary conclusion that can be drawn is that the synthesis of methyl esters in this study was successful because the viscosity of castor oil, which was originally at 701 cSt, decreased to 103.5 cSt, 43.55 cSt, and 62 cSt.

6) Refractive index

The refractive index is the ratio between the speed of light in air and the speed of light in a certain medium. One of the factors that influences the refractive index value is the temperature factor. If the temperature is too high, the methyl ester will undergo oxidation, breaking the double bonds in the fat molecules. The loss of double bonds causes the oil to become saturated and will reduce the refractive index value of the methyl ester [22]. The refractive index of the synthesized methyl ester is presented in Table 7.

Table 7. Characterization of Refractive Index of The Methyl Ester

CaO/K_2O	Temperature (ºC)	Refractive index (n')	Refractive index on 25ºC
1:1	27.7	1.468	1.469
1:2	28	1.465	1.466
2:1	28.2	1.466	1.467

CONCLUSION

Based on the results of this study that has been carried out, several conclusions are: (1) CaO/K_2O catalyst used in this research can help the transesterification process carried out on castor oil to produce methyl ester, because it is able to reduce free fatty acid levels, acid number and viscosity of oil triglycerides, (2) the synthesis results in this study are quite good seen from the comparison between density, acid number, free fatty acids, and viscosity of castor oil with its methyl ester, although it does not meet the quality standards specified, it is hoped that the synthesis of methyl ester from castor oil can be carried out using CaO/K_2O catalyst, (3) in this study CaO/K_2O concentrations used were 1:1, 1:2, and 2:1. Based on the results of the characterization of each concentration compared with SNI 7182:2015, it can be concluded that the best methyl ester results that are close to SNI come from transesterification of castor oil with 1:2 CaO/K_2O catalyst.

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