jTEP
JURNAL KETEKNIKAN PERTANIAN 10(3) 253-267 2022
P-ISSN 2407-0475 E-ISSN 2338-8439

The Effect of the Transesterification Process Using KOH Catalyst on the Characteristics of Biodiesel from Sterculia Foetida Seeds as an Alternative Fuel

Dani Hari Tunggal Prasetiyo[1*], Nasrul Ilminnafik[2], Alief Muhammad[1]
[1] Department of Mechanical Engineering, Faculty of Engineering, Panca Marga University
[2] Department of Mechanical Engineering, Faculty of Engineering, University of Jember
[*] Email correspondence: dani.hari58@yahoo.com

Info Artikel

Submitted: 27 June 2022
Accepted: 14 September 2022

Keyword:
Catalysts; Kepuh Biodiesel; Mixing Pure Diesel; Transesterification; KOH

Abstract

Research on renewable energy has become an interesting topic in the era towards industry 5.0. This was because the world's energy needs continue to increase every year, especially during the industrial revolution. The use of biodiesel as an alternative fuel began to be developed along with the emergence of policies for adding biofuels to fossil fuels. Kepuh oil has the opportunity to be developed as an alternative fuel as biodiesel feedstock. This was because kepuh oil contains triglycerides. The purpose of this study was to determine the effect of catalyst concentration on density, viscosity and heating value. The catalyst used to produce biodiesel was KOH. The concentration of the catalyst used was K-0.8%; K-0.9%; K-1.0%; K-1.1% and K-1.2%. Biodiesel production was carried out at a temperature of 600C for 1 hour in the esterification and transesterification processes at the same temperature and time. The best production of kepuh biodiesel was obtained at a catalyst concentration of K-0.8% with a density value of 0.83 gr/ml, a viscosity of 2.8 cst and a heating value of 9,847 cal/gr, while the best results were obtained from mixing pure diesel with kepuh biodiesel at a catalyst concentration K-0.8%. The test resulted in a density value of 0.82 gr/ml, a viscosity of 2.24 cst, and a heating value of 10,658 cal/gr. The highest yield was 77.3% at 1.2% catalyst concentration

Doi: https://doi.org/10.19028/jtep.10.3.253-267

1. Introduction

Research and discovery of renewable fuel energy sources has always been an interesting topic in the world, such as biogas (Prasetiyo et al., 2021), biomass (Sukarni et al., 2017) dan biofuels to use in catalyst-based combustion and pyrolysis (Sukarni et al., 2020). The world's energy needs were always increasing, so solutions were needed to meet energy needs (Ghasemian et al., 2020). If you only rely on fossil energy sources, it will certainly cause problems in the future. However, that did not mean that fossil energy sources were abandoned. While there was still time and there were still fossil energy sources remaining, it was necessary to optimize the use of renewable energy sources. This is very necessary because the increasing population growth is followed by an increase in the amount of energy demand.

The use of fossil energy continues to increase causing fossil energy reserves in nature to be depleted. One of the depleting fossil energy reserves was petroleum. If oil was explored continuously, oil reserves will be exhausted in the future (Dongoran et al., 2022). This encourages researchers to look for alternative and renewable energy sources. Even though alternative energy sources currently cannot be used 100%, at least mixing alternative energy with fossil energy can provide even longer opportunities to supply energy to the world. One alternative energy that can be used as a mixture of fossil fuels was biodiesel (Al-Mahbuby, 2019).

Mixed fuels are combinations of fossil fuels with alternative fuels. Current blended fuel products are made with pure diesel fuel (fossil fuel) with biodiesel from palm oil. However, currently the raw material for biodiesel still relies on palm oil, while palm oil is a basic need of the community which is used as cooking oil to process food. This will cause future economic crises and trigger a spike in food prices. Therefore, further research is needed to find biodiesel raw materials other than palm oil.

Biodiesel raw materials can be obtained from seeds that were rich in oil, one of which was kepuh (Sterculia foetida) seeds. Kepuh seeds can produce crude oil which can be processed into biodiesel (Prasetiyo et al., 2022). This was because kepuh crude oil contains long chain fatty acids, so it meets the main requirements for biodiesel feedstock. In addition, kepuh oil as raw material for biodiesel had not affect the economic impact, this was because kepuh oil was not a raw material that can be consumed.

Currently, the wood of the kepuh plant was still used. Kepuh tree wood was used to make furniture needs. However, the utilization of kepuh seeds as biodiesel was still rarely maximized. Therefore, research was needed on the manufacture of biodiesel from kepuh oil. Kepuh biodiesel was expected to be a mixture of diesel fuel sourced from fossil energy so that it can save the remaining energy reserves.

In general, biodiesel production was carried out by esterification and transesterification stages (Elma et al., 2018). The results of the esterification and transesterification stages produce their own properties or characters in biodiesel. The purpose of combining esterification and transesterification reactions was to produce biodiesel characteristics that meet predetermined standards. Therefore, two stages were needed in the biodiesel production process.

The esterification step was carried out to reduce the free fatty acid content in the oil. The esterification step was carried out by adding alcohol.. However, in the esterification stage a catalyst was also required. The catalyst used in the esterification step was a strong acid catalyst. Biodiesel raw materials that contain free fatty acids of more than 5%, an esterification step was required. At this stage the free fatty acids will be converted into alkyl esters. After the esterification stage followed by the transesterification stage.

In the transesterification stage, there was a conversion process of triglycerides into methyl esters. The biodiesel production process cannot be separated from the role of the catalyst used in the transesterification stage. Catalysts were chemical elements used to speed up reactions during the biodiesel fuel production process. Types of catalysts used include enzymatic catalysts, homogeneous catalysts and heterogeneous catalysts (Saimon et al., 2021). KOH (Potassium Hydroxide) was a kind of homogeneous catalyst (Sukarni, et al., 2020). A homogeneous catalyst was a catalyst that was in the same phase as the reactants. It can be seen that the reactants used were in a liquid phase so that the catalyst also has a liquid phase. KOH catalyst was a homogeneous catalyst which had advantages such as affordable price, easy to obtain and high catalyst yield (Suleman et al., 2019) .

Furqon (2019) conducted research on biodiesel production using KOH catalyst. The results showed that the use of KOH as a catalyst met the requirements of SNI biodiesel SNI-04-7182-2015. The concentration of the KOH catalyst used was 0.5 so as to produce a methyl ester content of 97.5%. Andalia (2018) also conducted research on biodiesel production by comparing the quality of the catalyst. The catalysts used were NaOH and KOH. The results showed that the use of NaOH and KOH catalysts produced the same good quality. This can be seen from the density and viscosity values that have met the established SNI (Indonesian National Standard). However, the use of NaOH catalyst was better than KOH, this was obtained from the yield percentage data produced. The yield of NaOH catalyst was higher than that of KOH catalyst with a value of 94.4% for KOH catalyst and 98.89% for NaOH catalyst.

Research on the production process of alternative fuels, one of which was biodiesel fuel, had been widely carried out. However, further research on the effect of catalysts on biodiesel production results also needs to be done. This was so that the biodiesel production process can produce maximum quality and meet the standards that have been set. The biodiesel standard was issued by the National Standardization Agency (BSN) with the number SNI 7182:2015 which refers to the Indonesian National Standard (SNI) for biodiesel.

This research was conducted to determine the effect of the concentration of KOH catalyst using kepuh oil as biodiesel fuel. In addition, information was needed on the effect of adding kepuh biodiesel to diesel fuel obtained from fossil energy sources on the characteristics of the fuel. The expected results were information or data on the optimal amount of catalyst concentration to produce biodiesel as an alternative fuel and the effect of adding kepuh biodiesel to pure diesel on the characteristics of the resulting fuel.

2. Materials and Methods

In this study, the method used was an experimental method by varying the concentration of the catalyst in the transesterification stage. This study used three types of variables. Research variables consist of independent variables, dependent variables and controlled variables. The independent variable in this study was the concentration of the catalyst. The type of catalyst used in this research was KOH (potassium hydroxide). Variations in the concentration of the catalyst used were K-0.8%; K-0.9%; K-1.0%; K-1.1% and K-1.2%. The dependent variables in this study were calorific value, density, viscosity and yield. The control variables in this study were the composition of methanol with kepuh oil, temperature and time during the esterification-transesterification process, and the composition of mixing pure diesel fuel (fossil diesel fuel) with kepuh biodiesel. The flow of the research process can be observed in Figure 1 and then proceed with the production stage which was described in the following subchapter.

Figure 1. Biodiesel production process flow chart

2.1 Pressing Process

The kepuh biodiesel production process begins with the pressing process on the kepuh fruit seeds. The pressing process aims to obtain crude oil. The pressing process is carried out using five samples. The results of pressing are calculated the average volume of oil produced. The average volume of oil produced is calculated by standard deviation using equation 1. After crude oil is obtained, proceed to the next stage, namely the degumming process.

$$S = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n}} \tag{1}$$

Explanation :

S : Standard deviation

Xi : i-th x value

$\bar{X}$: average value of data

n : amount of data

2.2 Degumming process

The degumming stage is carried out to remove the sap/dirt on the kepuh oil. The degumming process is done by adding H_3PO_4. H_3PO_4 added as much as 1% of the total mass of oil. After the H_3PO_4 and oil were mixed, it was continued with the stirring process between the oil and H_3PO_4 for 30 minutes at a temperature of 60^0C. The results of the degumming process are calculated using equation (2).

$$Yield = \frac{Weight\ of\ kepuh\ oil\ sample\ after\ degumming\ process}{Weight\ of\ kepuh\ oil\ sample} \times 100\% \tag{2}$$

2.3 Titration Process

The process of made biodiesel before the esterification process was the process of determining the levels of free fatty acids (FFA) contained in the oil. Alkalimetric titration method was carried out to determine the value of the free fatty acid number in kepuh oil. Free fatty acids were one of the determining factors for biodiesel production. Based on the test results, kepuh oil contains a free acid content of 18.7%. The high free fatty acid content of kepuh oil and above 5% cannot be directly processed to the transesterification stage. Therefore, the kepuh biodiesel production process must go through the esterification stage first. This was done to reduce the free fatty acid content to less than 2%. The titration method uses phenolphthalein and potassium hydroxide (KOH) as indicators. The equation used in the titration method can be seen in equation 3 as follows.

$$Rate(\%)\left(\frac{m}{v}\right) = \frac{M \times V \times Mr}{1000 \times V_{sample}} \times 100\% \tag{3}$$

Explanation :

M : Solution concentration (M)

V : Titrant volume (ml)

Mr : Relative mass (g/mol)

Vsample : Sample volume (ml)

2.4 Esterification Process

The esterification step was carried out to reduce the free fatty acid content in kepuh oil. This was because the free fatty acids of kepuh oil were more than 2%. The results of the esterification process were analyzed to determine the content of free fatty acids using the titration method. After the fatty acid content was less than 2%, it was continued with the transesterification stage. In this study, the esterification process was repeated twice. This was because the free fatty acid content in kepuh oil was high, so more than one esterification process was needed. If the esterification process had been carried out twice, but the free fatty acid content was still more than 2%, then the esterification process was repeated until the free fatty acid content was less than 2%. The esterification process was repeated at the same time and temperature.

The esterification process is carried out by mixing kepuh oil and methanol by adding H_2SO_4. The ratio of the composition of kepuh oil with methanol is 1:1.5 (mass/mass), then 1% H_2SO_4 is added from the total mass of kepuh oil. After mixing, the esterification process was carried out by stirring the kepuh oil, methanol and H_2SO_4 using a magnetic stirrer. Stirring was carried out for 60 minutes at a temperature of 60°C.

2.5 Transesterifikasi Process

The transesterification process aims to convert glycerol alkyl alkanoate from triglycerides into methyl esters (Adhani et al., 2016). The composition in the transesterification process uses a mass ratio. Mass ratio between oil and methanol 1:0.5 (1 kepuh oil: 0.5 methanol) (mass/mass) then added KOH as a catalyst. The variation of catalyst concentration is K-0.8%; K-0.9%; K-1.0%; K-1.1% and K-1.2% of the total mass of oil. The catalyst concentration was varied to obtain the best concentration information for the production of kepuh biodiesel. Catalyst serves to speed up the biodiesel production process. If the production process does not use a catalyst, the reaction tends to be slower and biodiesel will take longer to produce. Glycerol alkyl alkanoate, methanol and KOH were stirred with a magnetic stirrer at 60^{0}C for 60 minutes. After the stirring was completed, the product was precipitated for eight hours.

2.6 Purification Process

The purification process was carried out by washing the biodiesel with distilled water (Arenas et al., 2021). The ratio of biodiesel and distilled water is 1:1 (1 biodiesel: 1 water) (mass/mass) using the mass ratio. The steps are carried out by preheating distilled water to a temperature of 80^{0}C. Then the distilled water is put into a measuring cup containing biodiesel. After completion of stirring, the product is placed in a separatory funnel for a precipitation process for 1 hour.

2.7 Heating Process

The biodiesel heating process was carried out to remove the remaining water and methanol remaining in the kepuh biodiesel. The heating process was carried out on all kepuh biodiesel products. Heating was carried out in a measuring cup placed on a magnetic stirrer at a temperature of 80°C for 180 seconds. This process aims to evaporate the remaining methanol and aquades that ware still left in the biodiesel.

2.8 Yield

After going through the heating process, the biodiesel product produced in each sample needs to be analyzed. This aims to determine the effect of catalyst concentration on the resulting biodiesel product. The sample of kepuh oil used to produce biodiesel was 100 ml. To get the yield value can be calculated using equation (4).

$$Yield = \frac{WB}{WS} \times 100\% \tag{4}$$

Explanation :

WB : The weight of the biodiesel sample corresponds to the variation of the catalyst concentration

WS : Weight of kepuh oil sample.

2.9 Fuel Mixing Process

Mixed fuel was a combination of pure diesel fuel (diesel fuel sourced from fossil energy) with kepuh biodiesel fuel. Pure diesel fuel used in this research was dexlite type diesel, while the biodiesel fuel used was kepuh biodiesel. The percentage ratio of fuel blending was 8:2 (80% pure diesel : 20% kepuh biodiesel). The mixing process uses a magnetic stirrer to stir the fuel so that the fuel was mixed homogeneously. Stirring was done for 180 seconds. Biodiesel products with various catalyst concentrations were mixed with pure diesel fuel. The results of mixing are measured by the calorific value, viscosity and density of each type of fuel.

2.10 Calorific Value

The calorific value was measured using the Bomb Calorimeter System, brand PAAR and model PAAR 1241 EF with a voltage of 220 Volts. Prior to use, the test equipment was calibrated using benzoic acid. Bomb calorimeter system functions to burn fuel adiabatically by using an insulator. When there was an increase in temperature, this temperature was used to calculate the calorific value produced.

2.11 Viscosity

The tool used in the viscosity test was Herzog Saybolt with the ABR NL 90212 model with a power of 5,000 watts. The test equipment serves to determine the value of viscosity (thickness number) in oil/fuel products. In viscosity testing, the test equipment requires 50 ml of the material to be tested. The material to be tested was put into a measuring tube, then a stopwatch was also prepared to calculate how long the ball will fall during the viscosity test. Water was put into a heating tube at a temperature of 400C. Water as a heating medium will transfer heat energy around the tube containing the test material. After the tools and materials were ready to be tested, the cover tube was opened and the ball was inserted into the test material. When you're done, record the length of time the ball reaches the bottom of the tube. After completing the calculation using equation 5 as follows.

$$V = 0.0026t - 1.175/t \tag{5}$$

Explanation :

V : Kinematic viscosity on stoke (cst)

t : Time until the ball reaches the bottom of the tube (s)

2.12 Density

Density was one measure of mass in each unit volume of fluid. The density of the fluid can be obtained from the total mass divided by the total volume. Density testing on the sample begins with preparing a hydrometer and the sample to be tested for its density value. The sample was put into a tube or measuring cup with a volume of 100 ml. Then proceed with inserting the hydrometer into the tube containing the sample to be tested. Care must be taken when measuring density when inserting the hydrometer into the tube containing the sample. This was done to avoid the occurrence of air bubbles when the hydrometer enters the tube containing the sample. Then to read the results of the density test can be seen on the scale contained in the hydrometer. The scale indicated by the hydrometer was the relative density of the sample. After the process of testing the calorific value, density and viscosity of the kepuh biodiesel had been carried out and had met the biodiesel standards that had been set according to the SNI 7182:2015 standard, the next step was to test the characteristics of the fuel mixture.

3. Results and Discussion

3.1 Kepuh Seed Pressing Results

Making biodiesel with kepuh oil as raw material begins with the pressing process. The seeds of the fruit contain oil that can be used as raw material for biodiesel. The results obtained from the pressing process can be seen in Table 2. Pressing was carried out for five samples with the sample code (S). In Table 2 it can be seen that the average mass of oil obtained was 402.6 grams with a standard deviation of 12,239 for every 1,000 grams of kepuh seeds. This shows that kepuh seeds can produce a fairly high oil yield. The free fatty acid content of kepuh oil in this study was 18.7%. The high value of free fatty acids in kepuh oil requires the esterification process to be carried out first and then followed by the transesterification process.

Table 2. Kepuh seed oil from the pressing process

Sample	Seed Weight (grams)	Oil Obtained (grams)
S-1	1,000	386
S-2	1,000	404
S-3	1,.000	418
S-4	1,000	396
S-5	1,000	409
Average oil retrieved		402.6
Standard deviation		12.239

3.2 Degumming process

The degumming process aims to separate the gum. Gum was a gum in oil consisting of phospholipids, proteins, residues, carbohydrates, water and resins (Adekunle et al., 2016). The results of the degumming yield of kepuh oil by comparing other raw materials can be seen in Table 3. The equation used to obtain the yield value of the degumming process uses equation (2).

Table 3. Degumming results

Sample	Yield
Kepuh oil	81,34%
Randu oil *	71,91%
Mahoni oil **	79,42%
Palm waste oil ***	89%

Source : (Kharis et al., 2019)* (Damayanti et al., 2013)** (Budiyanto et al., 2012)***

The results of the degumming process show that kepuh oil has the same yield as other biodiesel feedstocks. This shows that the percentage of gum in kepuh oil is 18.66%. After the degumming process continued with the esterification process.

3.3 Esterification Process

The kepuh oil esterification process was carried out twice. This was because the free fatty acids of kepuh oil have a value of 18.7%. Esterification was carried out using five samples of kepuh oil with code (S). The results of the esterification process can be seen in Table 4 while the standard deviation value in the esterification process was obtained using equation (1).

Table 4. The results of free fatty acid esterification of kepuh crude oil

Sample	FFA content before esterification (%)	FFA content in the first esterification (%)	FFA content in the second esterification (%)
S-1	18.7	10.1	1.3
S-2	18.7	9.7	0.9
S-3	18.7	10.4	1.5
S-4	18.7	9.9	0.9
S-5	18.7	10.3	1.8
Average FFA content		10.08%	1.28%
Standard deviation		8.94%	8.94%

Based on Table 4, kepuh oil can be reduced its free fatty acid content to less than 2%. Free fatty acid levels in the sample of less than 2% can be continued to the transesterification stage.

3.4 Transesterification Process

In Figure 2 can be observed the transesterification reaction. The transesterification process produces glycerol which was formed from triglycerides, diglycerides, and monoglycerides (Cercado et al., 2018). In this study, the catalyst used was KOH. The concentration of the KOH catalyst was varied. Then, the kepuh biodiesel product that has been produced according to the variation of the catalyst concentration was mixed with pure diesel fuel. This aims to determine the characteristics of pure diesel fuel when mixed with kepuh biodiesel. In addition, mixing kepuh biodiesel with pure diesel fuel (fossil diesel fuel) is to save diesel fuel from fossil energy so that it is not focused on palm oil as a raw material for diesel fuel mixtures. As a reference, the characteristics of pure diesel can be seen in Table 5 and the results of the mixing can be seen in Figures 3 to 5.

Table 5. Characteristics of pure diesel fuel

Specifications	SNI 7182:2015 Biodiesel	Diesel
Density (gr/ml)	0,815-0,890	0,817
Viscosity (cst)	2.0 – 6.0	2.2
Calorific value (cal/gr)	10,602	10,743

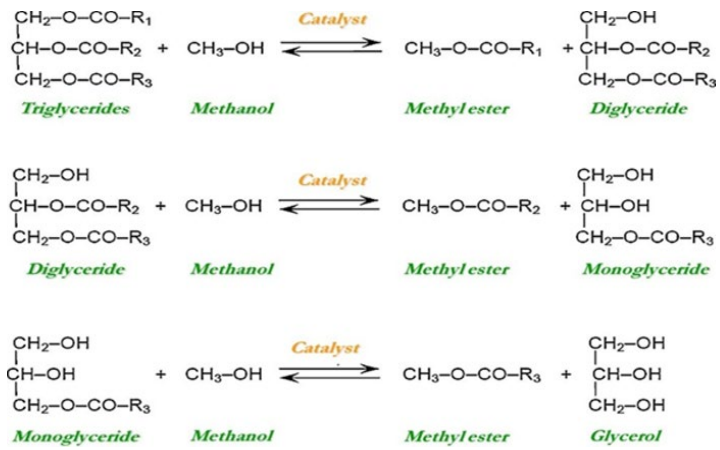

Figure 2. Transesterification reactions (Cercado et al., 2018)

3.5 Density

The test results began by testing the density value of the kepuh biodiesel and the density value of the mixed fuel. The results of the density value test can be observed in Figure 3.

Density or density was the ratio of mass in a volume of fluid with the same temperature and volume (Landi et al., 2017). In Figure 3 can be observed the relationship of density values with variations in the amount of catalyst. The highest density value was found in the use of 1.2% catalyst at 0.883 gr/ml while the lowest density value was found in the use of K-0.8% catalyst at 0.837 gr/ml. Variation of catalyst concentration in the transesterification process using KOH catalyst did not significantly affect the density value. This can be observed from the difference in the resulting density values. In the variation of the catalyst concentration K-0.8%; K-0.9%; K-1.0%; K-1.1% and K-1.2% have density values of 0.837 gr/ml, 0.841 gr/ml, 0.858 gr/ml, 0.870 gr/ml and 0.883 gr/ml, respectively. However, the density value of kepuh biodiesel with various KOH catalysts meets the established SNI 7182:2015 standard. The minimum standard of biodiesel density that was allowed to be produced was 0.815 gr/ml and the highest was 0.89 gr/ml.

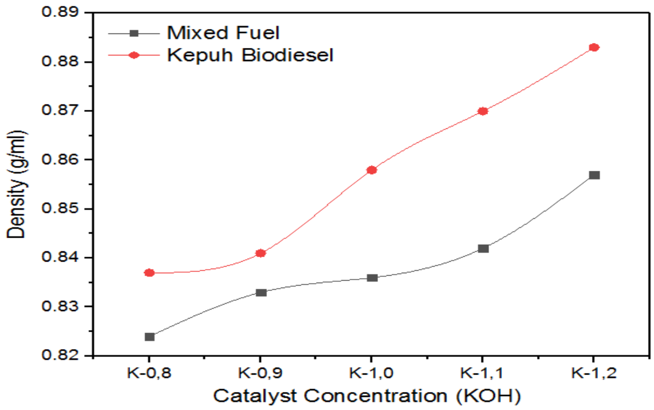

Figure 3. Graph of density relationship with catalyst concentration

The relationship between catalyst concentration and density value can be seen in Figure 3, the higher the catalyst concentration, the higher the density value. This shows that there was an effect of catalyst concentration on the density value, although it was not significant. The density value which increases with increasing catalyst concentration was influenced by the length of the carbon chain. As the catalyst concentration increases, the carbon chain length decreases. In addition, the higher the catalyst concentration, the higher the number of double bonds in the fatty acids. The lower the saturation point of kepuh oil, the higher the density value. Density values in biodiesel that exceed the standard should not be used. This will trigger damage and wear on the engine elements.

The test was continued by adding kepuh biodiesel to pure diesel fuel (fossil fuel). The combination of pure diesel fuel with kepuh biodiesel was called mixed fuel. The test results can be seen in Figure 3. The mixed fuel produces a density value according to the SNI 7182:2015 standard. The permissible density value of diesel fuel according to the SNI 7182:2015 standard was at least 0.815 gr/ml while the maximum was 0.89 gr/ml. The addition of kepuh biodiesel to pure diesel produces a fuel density value of not less than 0.815 gr/ml and not exceeding 0.89 gr/ml.

The kepuh biodiesel product according to the variation of the catalyst concentration was mixed in pure diesel fuel to produce a density value. The mixed fuel had a density value of 0.824 gr/ml, 0.833 gr/ml, 0.836 gr/ml, 0.842 gr/ml and 0.857 gr/ml. If it was observed that the density value of the mixed fuel meets the standard of SNI 7182: 2015. However, pure diesel fuel after being mixed with kepuh biodiesel had an increase in its density value. It can be observed in Table 5, the density value of pure diesel fuel used in this study was 0.817 gr/ml.

The results showed that kepuh biodiesel could increase the density value of pure diesel fuel. This was because kepuh biodiesel has glycerol contained in methyl esters so that it affects the density value of the fuel. In addition, monoglycerides and diglycerides contained in kepuh biodiesel also affect the density value. This causes a fairly high polarity and weight in the fuel mixture. In addition, kepuh biodiesel contains a lot of triglycerides so that the density value was higher than pure diesel fuel. When pure diesel fuel was mixed with kepuh biodiesel, the triglyceride content in pure diesel fuel increases.

3.6 Viscosity

Viscosity was one of the characteristics of diesel fuel that needs to be considered. This was because viscosity affects the internal combustion process in diesel engines. The lower the viscosity value of the fuel, the easier it was to atomize the fuel in the combustion chamber. However, the viscosity of diesel fuel has a predetermined standard value. Viscosity value according to SNI 7182:2015 was allowed a minimum of 2.0 cst and a maximum of 6.0 cst.

The relationship between catalyst concentration and viscosity of kepuh biodiesel can be seen in Figure 4. In Figure 4 the highest viscosity value of kepuh biodiesel lies in the catalyst concentration of 1.2% at 3.40 cst while the lowest viscosity value lies in the use of K-0.8% catalyst. at 2.24 cst. It can be observed in Figure 3, the viscosity value with the variation of the catalyst concentration K-0.8%; K-0.9%; K-1.0%; K-1.1% and K-1.2% resulted in viscosity values of 2.8 cst, 3.01 cst, 3.28 cst, 3.34 cst and 3.40 cst. This shows that there was an effect of catalyst concentration on the viscosity value, although it was not significant. However, the viscosity value of kepuh biodiesel meets the standards according to SNI 7182:2015.

In Figure 4 can be observed the effect of catalyst concentration on the viscosity value of kepuh biodiesel. As the concentration of KOH catalyst increases, the viscosity of the fuel also increases. This was due to the content of free fatty acids and unsaturated acids remaining in the kepuh biodiesel. Free fatty acids and unsaturated acids cause the intermolecular density to be narrower. The narrower intermolecular density due to the remaining free fatty acids and unsaturated acids causes the catalyst was not optimal to reduce the activation energy.

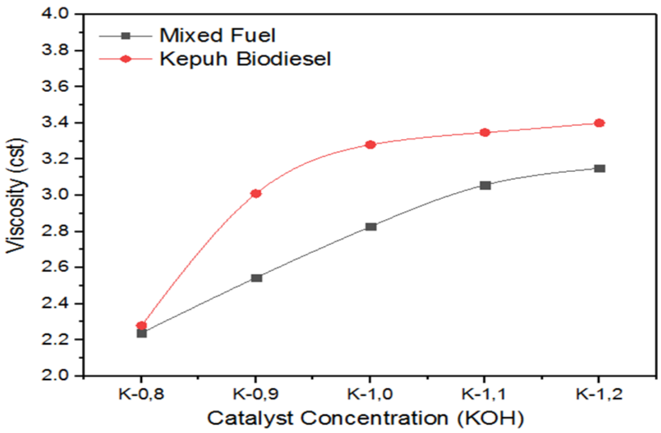

Figure 4. Graph of viscosity relationship with catalyst concentration

In accordance with the research method, the research was continued by adding kepuh biodiesel to pure diesel fuel. The results of the study can be seen in Figure 4. The results of adding biodiesel to pure diesel caused the viscosity value to increase. The viscosity value of the mixed fuel was higher than that of pure diesel fuel. This provides information that the addition of kepuh biodiesel to pure diesel can increase the viscosity value although it does not provide a significant increase. However, the results of mixing kepuh biodiesel in pure diesel produced a viscosity value that was in accordance with the SNI

7182:2015 standard. The result of mixing produces a viscosity value of not less than 2.0 cst and not exceeding 6.0 cst. The viscosity value of the mixed fuel was in accordance with the SNI 7182:2015 standard.

Pure diesel viscosity increases when mixed with kepuh biodiesel, this was due to the free fatty acid content and the number of double bonds in kepuh biodiesel. The content of free fatty acids and the number of double bonds in kepuh biodiesel increases, causing the viscosity of the mixed fuel to increase. Viscosity that does not meet the standards will result in blockage of the injectors and deposition in the fuel storage area. Therefore, the viscosity of the fuel used must comply with established standards.

3.7 Calorific Value

The calorific value of a fuel was the energy content of the fuel. In Figure 5, it can be observed that the heat relationship of steamed biodiesel with catalyst concentration can be observed. The higher the concentration of KOH catalyst, the lower the calorific value produced. The highest calorific value of kepuh biodiesel lies in the K-0.8% catalyst concentration of 9.847 cal/gr while the lowest calorific value lies in the 1.2% catalyst of 9.325 cal/gr. Calorific value of kepuh biodiesel according to catalyst variation K-0.8%; K-0.9%; K-1.0%; K-1.1% and K-1.2% were 9,847 cal/gr, 9,642 cal/gr, 9,514 cal/gr, 9,423 cal/gr and 9,325 cal/gr. This shows that the more the catalyst, the lower the calorific value produced. This was influenced by the density of the fuel. In the density of fatty acid composition, the higher the fatty acid, the lower the calorific value. Therefore, the calorific value was inversely proportional to the density. In addition, the calorific value was affected by the carbon content. The higher the carbon content, the higher the calorific value of biodiesel, the lower the carbon content the lower. catalyst concentration leading to lower carbon content.

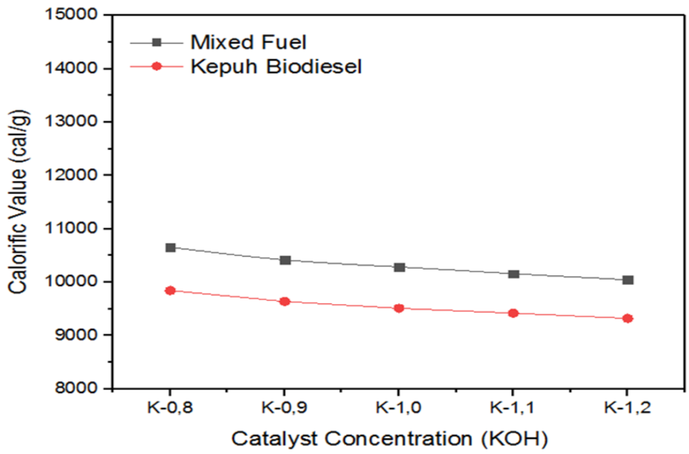

Figure 5. Graph of calorific value relationship with catalyst concentration

In accordance with the research method, the research was continued by adding kepuh biodiesel to pure diesel fuel. The ratio of pure diesel fuel mixture with kepuh biodiesel fuel was 8:2. The comparison was based on diesel circulating in Indonesia with a composition of 80% pure diesel fuel with 20% biodiesel fuel. This research was conducted so as not to be pushed by palm oil as a biodiesel feedstock. The results of mixing diesel fuel with kepuh biodiesel products according to the catalyst concentration (K-0.8%; K-0.9%; K-1.0%; K-1.1% and K-1.2%) resulted in calorific value of 10,658 cal/gr, 10,421 cal/gr, 10,287 cal/gr, 10,162 cal/gr and 10,049 cal/gr. The Calorific value of pure diesel with kepuh biodiesel has decreased. When compared with the calorific value of kepuh biodiesel, the calorific value of pure diesel fuel was greater, namely 10,743 cal/gr. This was because the value of the density and viscosity of the mixed fuel increases. The increase in density and viscosity causes the fuel molecules to get closer together. As the fuel molecules get closer to each other, the fuel will have a harder time releasing energy. It can be concluded that the process of mixing kepuh with pure biodiesel can reduce the calorific value specifications.

3.8 Biodiesel Yield of Kepuh

In Figure 6 it can be seen the relationship between the yield of kepuh biodiesel and the concentration of the catalyst. To get the yield value, you can use equation 4. It can be seen in Figure 6, the higher the catalyst concentration, the more yield was produced.

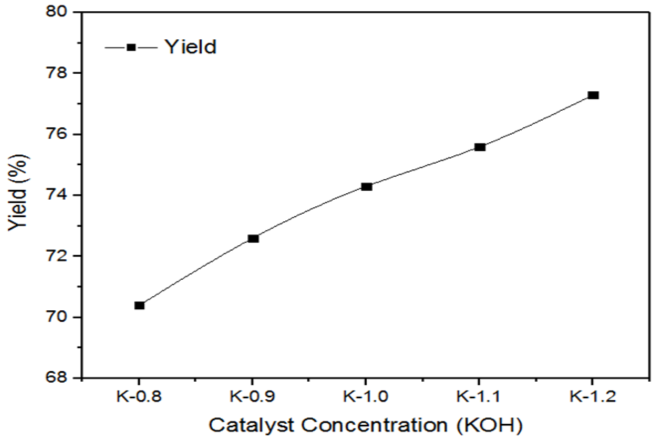

Figure 6. The relationship between catalyst concentration and steam. biodiesel yield

However, the difference in the results obtained was not very significant. The highest yield was found in the catalyst concentration of 1.2% at 77.3% while the lowest yield was at 70.4%. The catalyst concentration affects the yield of biodiesel produced. This was because the catalyst can minimize the formation of soap during the transesterification process so that more biodiesel was produced compared to the lower catalyst concentration.

4. Conclusion

The conclusion of the research on the effect of the transesterification process using a KOH catalyst on the characteristics of biodiesel from kepuh (sterculia foetida) seeds as an alternative fuel was as follows:

1. Kepuh seeds produce an average oil yield mass of 402.6 grams with a standard deviation of 12.239 grams.
2. The esterification process was carried out to reduce free fatty acids in kepuh oil. The esterification process in this study was carried out twice. In the first stage of the esterification process, the average free fatty acid was 10.08% with a standard deviation of 8.94%, while in the second stage the average free fatty acid was 1.28% with a standard value of 8.94%.

3. The highest calorific value in kepuh biodiesel was 9.847 cal/gr while the mixed fuel was 10,558 cal/gr with a catalyst concentration of K-0.8%. The lowest calorific value of kepuh biodiesel was 9.325 cal/gr while the mixed fuel was 10,449 cal/gr with a catalyst concentration of K-1.2%.
4. The highest density in kepuh biodiesel was 0.87 gr/ml while in mixed fuel it was 0.89 gr/ml with a catalyst concentration of K-1.2%. The lowest density in kepuh biodiesel was 0.837 gr/ml while in mixed fuel it was 0.824 gr/ml with a catalyst concentration of K-0.8%
5. The highest viscosity of kepuh biodiesel is 3.21 cst while the mixed fuel is 3.05 cst with a catalyst concentration of K-1.2%. The lowest viscosity in kepuh biodiesel is 2.6 cst while in mixed fuel it is 2.34 cst with a catalyst concentration of K-0.8%.
6. The highest yield was found at a catalyst concentration of K-1.2% at 77.3% while the lowest yield was found at 70.4% at a catalyst concentration of K-0.8%.

5. References

Adekunle, A. S., Oyekunle, J. A. O., Obisesan, O. R., Ojo, O. S., & Ojo, O. S. (2016). Effects of degumming on biodiesel properties of some non-conventional seedoils. *Energy Reports*, *2*, 188–193. https://doi.org/https://doi.org/10.1016/j.egyr.2016.07.001

Adhani, L., Aziz, I., Nurbayti, S., & Octavia, C. A. (2016). Pembuatan Biodiesel dengan Cara Adsorpsi dan Transesterifikasi Dari Minyak Goreng Bekas. *Jurnal Kimia VALENSI*, *2*(1), 71–80. https://doi.org/10.15408/jkv.v2i1.3107

Al-Mahbuby, H. F. (2019). *Karakteristik Pembakaran Premix Biosolar Dengan Penambahan Biodiesel Minyak Jelantah*.

Andalia, W., & Pratiwi, I. (2018). Kinerja Katalis NaOH dan KOH ditinjau dari Kualitas Produk Biodiesel yang dihasilkan dari Minyak Goreng Bekas. *Jurnal Tekno Global*, *7*(2), 32–36. http://ejournal.uigm.ac.id/index.php/TG/article/view/549

Anwar, H., Widjaja, T., & Prajitno, D. H. (2021). Produksi Biogas dari Jerami Padi Menggunakan Cairan Rumen dan Kotoran Sapi. *CHEESA: Chemical Engineering Research Articles*, *4*(1), 1. https://doi.org/10.25273/cheesa.v4i1.7406.1-10

Arenas, E., Villafán-Cáceres, S. M., Rodríguez-Mejía, Y., García-Loyola, J. A., Masera, O., & Sandoval, G. (2021). Biodiesel Dry Purification Using Unconventional Bioadsorbents. In *Processes* (Vol. 9, Issue 2). https://doi.org/10.3390/pr9020194

Budiyanto, Dulay, H. B., & Aldiona, A. F. (2012). Optimalisasi Kinerja Pembuatan Dan Peningkatan Kualitas Biodisel Dari Fraksi Minyak Limbah Cair Pengolahan Kelapa Sawit Dengan Memanfaatkan Gelombang Ultrasonik. *Jurnal Teknologi Industri Pertanian*, *20*(1), 10–14.

Cercado, A. P. I., Jr, F. C. B., & Capareda, S. C. (2018). Biodiesel from three microalgae transesterification processes using different homogenous catalysts. *International Journal of Technology*, *9*(4), 645–651. https://doi.org/10.14716/ijtech.v9i4.1145

Damayanti, A., & Bariroh, S. (2013). PENGOLAHAN BIJI MAHONI (Swietenia Macrophylla King) SEBAGAI BAHAN BAKU ALTERNATIF BIODIESEL. *Jurnal Bahan Alam Terbarukan*, *1*(1), 74525.

Dongoran, S., Wulandani, D., & Desrial. (2022). *j TEP Investigation of Fluid Flow in Biodiesel Reactor with 4 Different*. *7*(3), 133–143.

Elma, M., Suhendra, S. A., & Wahyuddin, W. (2018). Proses Pembuatan Biodiesel Dari Campuran Minyak Kelapa Dan Minyak Jelantah. *Konversi*, *5*(1), 8. https://doi.org/10.31213/k.v5i1.23

Furqon, F., Nugroho, A. K., & Anshorulloh, M. K. (2019). Kajian Penggunaan Katalis KOH pada Pembuatan Biodiesel Menggunakan Reverse Flow Biodiesel Reactor secara Batch. *Rona Teknik*

Pertanian, *12*(1), 22–31. https://doi.org/10.17969/rtp.v12i1.12508

Ghasemian, S., Faridzad, A., Abbaszadeh, P., Taklif, A., Ghasemi, A., & Hafezi, R. (2020). An overview of global energy scenarios by 2040: identifying the driving forces using cross-impact analysis method. *International Journal of Environmental Science and Technology*. https://doi.org/10.1007/s13762-020-02738-5

Kharis, N., Sutjahjono, H., Arbiantara, H., Setyawan, D. L., & Ilminnafik, N. (2019). Karakteristik Biodiesel dari Minyak Biji Randu (Ceiba Pentandra) dengan Proses Transesterifikasi Menggunkan Katalis NaoH. *Jurnal Energi Dan Manufaktur*, *12*(1), 37. https://doi.org/10.24843/jem.2019.v12.i01.p07

Landi, T., & Arijanto. (2017). Perancangan Dan Uji Alat Pengolah Sampah Plastik Jenis Ldpe (Low Density Polyethylene) Menjadi Bahan Bakar Alternatif. *Jurnal Teknik Mesin Undip*, *5*(1), 1–8.

Permanasari, A. A., Sukarni, S., Wulandari, R., Puspitasari, P., Mauludi, M. N., & Ramadani, R. (2020). Density, flash point, viscosity, and heating value of waste cooking biodiesel (B20) with bioadditive essential oil (lemon, lemongrass, eucalyptus). *Journal of Physics: Conference Series*, *1595*(1). https://doi.org/10.1088/1742-6596/1595/1/012005

Prasetiyo, D. H. T. (2020). *Karakteristik Pembakaran Biosolar Dengan Penambahan Biodiesel Kepuh (Stercuila Foetida)*.

Prasetiyo, D. H. T., & Wahyudi, D. (2022). Pengaruh komposisi etanol sebagai zat aditif pada Sterculia Foetida Methil Ester terhadap pembakaran difusi. *Turbo : Jurnal Program Studi Teknik Mesin*, *11*(1). https://doi.org/10.24127/trb.v11i1.1923

Prasetiyo, D. H. T., Wahyudi, D., & Muhammad, A. (2021). *The Effect of Biogas Purification Process Using Calcium Oxide-Based Sorbents on the Diffusion Flame Combustion Characteristics (Pengaruh Proses Pemurnian Biogas Menggunakan Kalsium Oksida Terhadap Karakteristik Pembakaran Api Difusi)*. *4*(3).

Saimon, N. N., Jusoh, M., Ngadi, N., & Zakaria, Z. Y. (2021). Development of Microwave-Assisted Sulfonated Glucose Catalyst for Biodiesel Production from Palm Fatty Acid Distillate (PFAD). *Bulletin of Chemical Reaction Engineering & Catalysis; 2021: BCREC Volume 16 Issue 3 Year 2021 (September 2021)DO - 10.9767/Bcrec.16.3.10520.601-622* .

Sukarni, S., Ardianto, P., Retno, W., Aloon, E. W., & Poppy, P. (2020). Thermal characteristic of tetraselmis chuii combustion influenced by titanium dioxide (Tio2) nanoparticle. *Key Engineering Materials*, *851 KEM*(August), 149–155. https://doi.org/10.4028/www.scientific.net/KEM.851.149

Sukarni, S., Partono, P., Krisdianto, D., & Wulandari, R. (2017). *Effect of Magnetic Field on Diesel Engine Power Fuelled with Jatropha-Diesel Oil*. *1*(1), 44–48. https://doi.org/10.17977/um016v1i12017p044

Sukarni, S., Widiono, A. E., Wulandari, R., Prasetiyo, A., & Puspitasari, P. (2020). Thermogravimetric Study on the Thermal Characteristics of Tetraselmis chuii Microalgae Pyrolysis in the Presence of Titanium dioxide. *Key Engineering Materials*, *851*, 156–163. https://doi.org/10.4028/www.scientific.net/KEM.851.156

Suleman, N., Abas, & Paputungan, M. (2019). Esterifikasi dan Transesterifikasi Stearin Sawit untuk Pembuatan Biodiesel. *Jurnal Teknik*, *17*(1), 66–77. https://doi.org/10.37031/jt.v17i1.54