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Research Paper

The Effects of Sodium Hydroxide (NaOH) Concentration and Reaction Temperature on the Properties of Biodiesel from Philippine Tung (Reutealis Trisperma) Seeds

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Abstract

Philippine Tung (*Reutealis trisperma*) is an indigenous nut which is a relatively new feedstock for producing biodiesel in Indonesia. The nature of NaOH base catalyst and reaction temperature plays an important role in the method of biodiesel processing. This study intended to assess the effects of different percentages of catalyst and several temperatures on physicochemical properties of Philippine Tung biodiesel. Transesterification process was done by mixing Philippine Tung oil with methanol and NaOH. NaOH weight to oil weight was at 0.25%, 0.5%,0.75% and 1%, the reaction temperature set up was at 60 °C and 70 °C, while molar ratio of methanol to oil was stated at 6:1. Yield, acid value, saponification value, density, and viscosity of biodiesel were significantly influenced by NaOH catalyst concentrations. Meanwhile, reaction temperature had no significantly influenced on the yield and viscosity. Philippine Tung biodiesel produced using 0.25% NaOH catalyst met the SNI 04-7182-2015 biodiesel standard of the properties investigated in this study (yield: 96.18%, acid value: 0.466 mg KOH/g, saponification value: 200.083 mg KOH/g, density: 0.889 g/mL, viscosity: 5.276 cSt).

Keywords: Biodiesel; Philippine Tung; Transesterification, Physicochemical properties

1. Introduction

Philippine Tung (Reutealis trisperma) is an indigenous nut that is a relatively new feedstock for producing biodiesel in Indonesia. Philippine Tung tree can grow and able to suit well to a variety environment in some areas in Indonesia. This plant has ability to raise in the areas up to 1,000 m above sea level, as it can be seen in many parts of Java island, Indonesia. It raises as a halt attaining 75 m in height and has a large and thick plant crowns. In addition, the tree can resist precipitation falling to the land hence preventing soil abrasion and raising the amount of water absorbed into the soil. Philippine Tung tree has many branched roots and profound tap roots to avoid avalanche. Therefore, it is superior to be applied as can provide as soil-preserving plant [1], [2].

Philippine Tung produces fruit with seeds containing high vegetable oil that can be used for several purposes. Philippine Tung oil is contained of some substances including a-elaeostearic acid, linoleic acid, oleic acid, palmitic acid and stearic, with the highest part is a-elaeostearic acid counted for 51% [1]. The oil has any poisonous substance, for instances a-elaeostearic acid, thus it

Figure 1. Philippine Tung fruit and seeds

is not recomended for food. Therefore, when this oil is used as biodiesel feedstock, there will be no rivalry with food needs. Furthermore, Philippine Tung contain organic coumpond for killing insects and paint preserving materials [2]. Philippine Tung's productivity per hectare can offset the productivity of other vegetable oil sources in Indonesia, such as Jathropa oil and palm oil.

Biodiesel can be obtained in the transesterification process by reacting vegetable oil with ethanol and a catalyst with a by-product in the form of glycerol [3]–[5]. This reaction is an equilibrium reaction to promote a shift to the right and the use excessive amounts of alcohol is necessary [6]. Biodiesel production can use a homogeneous base catalyst such as sodium hydroxide (NaOH)and calcium hydroxide (KOH) or an acid catalyst such as sulfuric acid (H_2SO_4). Nevertheless, the catalyst has a weakness that is hard in the process of separating the reaction products so that they become wasted materials [7], [8]. Homogeneous base catalysts have advantages compared to other types, have a fast biodiesel formation, and produce a large amount of yield [9].

Holilah et al. [10] investigated the manufacture of biodiesel from Philippine Tung oil using sulfuric acid as a catalyst for esterification process and using sodium hydroxide as a catalyst in the transesterification process. The studies indicated that there was an increase in biodiesel yield using catalyst concentration of 0.5-1.0 wt%,. Subsequently, the biodoesel yield was lower when using a catalyst of 1.5-2.0 wt%. The Optimum result was attained using 1wt% catalyst, 1:2 methanol/oil (wt/wt) at 65ºC and reaction for 1 hour with the yield of 95.5%. A study conducted by Widyasanti et al. [11] demonstrated that 65 °C was the best temperature at which Philippine Tung biodiesel was produced. Furthermore, the optimum time for the reaction was 0.5 hours and the Fatty acid methyl esters (FAME) increased with the increasing dimension of the stirrer. Nurjanah et al. [12] examined the effects of NaOH catalyst and duration of transesterification on Fatty Acid Methyl Ester characteristics from Philippine Tung. The study revealed that percentage of 0.75% catalyst used in a 2-hour transesterification reaction obtained the optimum yield of Fatty acid methyl esters.

Transesterification reaction using KOH catalyst at a range of 0.5–2.0% oil weight was done at the temperature of 65 °C by Anggraini et al [13]. The result indicated that catalyst of 0.5 to 1.0% wt will cause biodiesel yield raise while catalyst of 1.5–2.0% wt will cause biodiesel yield decline. The condition for optimum yield of 83.33% was reached by using KOH catalyst at 1% wt.

Furthermore, Anggraini has studied several parameters for producing Philippine Tung biodiesel. The esterification reaction had been carried out at a oil:methanol comparison of 3:1 for 2 hours. Transesterification had been done by varying the catalyst content and the temperature was stated at 65 °C for 1 hour. Optimal biodiesel yield can be achieved at 96.91%, at a concentration of 1% KOH catalyst by weight of oil, a ratio of 1:1 oil to methanol (wt/wt), and reaction temperature of 65ºC. Biodiesel has an acid value range of 0.41–0.56 mgKOH/g, kinematic viscosity 8.28–12.70 cSt density of 0.89–0.91 g/cm^3, cetane value of 58.2–63.3 and carbon residues from 0.23 to 0.59% by weight/weight [7]. Garusti et al [14] conducted experiment on producing Philippine Tung biodiesel using two different catalysts. The results showed that biodiesel properties with 0.75% NaOH was superior than that of 1% KOH catalyst.

Sari et al [15] conducted a study to examined the optimal state for producing biodiesel from Philippine Tung. The method used was oil extraction using solvent with a time interval of 1.5; 2; 2.5 hours and a solvent ratio of 0.25; 0.2; 0.17. Furthermore, esterification was conducted using a H_2SO_4 catalyst at a temperature of 60 °C for 1 hour. The ratio of oil and methanol was 4:1 (v/v) and transesterification was done at 50 °C for 30 minutes. The results revealed that the opimal duration and amount of solvent for better production was 2 hours and the ratio of solvent to Philippine Tung was 0.17. The density of biodiesel produced is 0.82 g/ml, kinematic viscosity is 4.07 cSt, FFA value is 1.4%, and the level of saponification is 274.4 49 mgKOH/gr.

Haryono et al [16] examained the consequence of duration of 1; 1.5; and 2 hours using an H_2SO_4 catalyst on the amount of fatty acids (FFA) on esterification of Philippine Tung oil and examining the action of the CaO/SiO2 catalyst over the trans-esterification process for the biodiesel production. A temperature of 60^{o}C, ratio of oil to methanol at 1:9, a duration of 2 hours and a catalyst content of 3% CaO/SiO was stated for the trans-esterification process. The process indicated that FFA levels decreased significantly from 12.5% to 0.65% for 1 hour reaction at the esterification stage and at 1.5; and 2 hours decreased the FFA levels to 0.58%; and 0.54% sequentially. The conversion of Philippine Tung oil to biodiesel by the introduction of CaO/SiO_2 catalyst indicated that the biodiesel complies with SNI 7182-2015, for the parameters of density, viscosity, water content, iodine number and cetane number.

As discussed in some literature reviews above, although there have been a number of studies on the production of Philippine Tung biodiesel and its properties using various catalysts and methods, the problem that has been highlighted was several characteristics of Philippine Tung biodiesel that do not meet the biodiesel standards according to SNI 7182 -2015. Furthermore, There were also a number of problems such as the larger catalyst content will encourage the formation of soap which makes the segregation and purifying of biodiesel harder. Some studies showed that the optimum time for reaction also diverse according to many factors including method of reaction and temperature reaction. Biodiesel raw material, catalyst type and its concentration can also give a different biodiesel result. A more research concerning biodiesel production from Philippine Tung is therefore very important to be conducted.

Research that discusses the impact of NaOH catalyst and temperature on the biodiesel properties of Philippine Tung is still relatively limited. Therefore it is sensible to modify the research variables (NaOH catalyst and temperature) that were not previously studied in order to determine the impact of NaOH catalyst content and temperature on the yield and the properties of biodiesel from Philippine Tung oil and comparing to SNI 7182 -2015. Therefore, this study was designed in a slightly differently from previous studies to fill the gap of some research variables that had not been carried out by previous researchers. For this purpose, the study was set to evaluate the influence of several variations of NaOH catalyst and reaction temperature with catalyst variations of 0.25%, 0.5%, 0.75%%, 1%, reaction temperature 60 °C and 70 °C, with a magnetic stirrer of 325 rpm for 1 hour on the yield and properties of biodiesel of Philippine Tung oil.

2. Materials and Method

2.1. *Material*

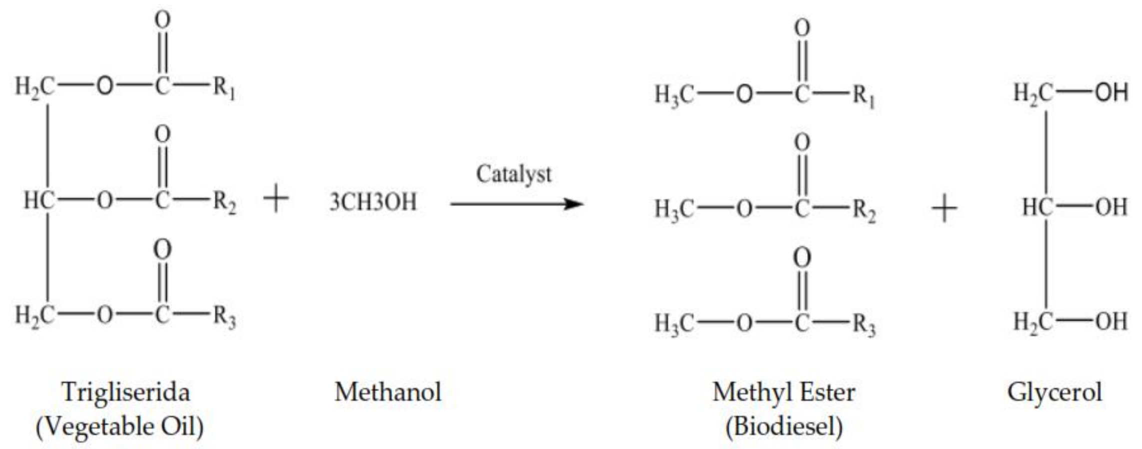
Philippine Tung (*Reutealis trisperma*) oil used in this research was collected from the local market in Garut region, West Java, Indonesia. Methanol (Merck 99%), NaOH (Merck 99,5%), H_2SO_4 (Merck 99,5%), aquadest were obtained from PT. Brataco Chem. Semarang, Indonesia.

2.2. *Procedure*

Properties of crude Philippine Tung (Reutealis trisperma) oil produced from dried kernel by mechanical pressure is shown in **Table 1**. The initial treatment on the crude oil was purification by degumming process to remove the gum content in crude oil. The following esterification process was carried out by mixing 20% methanol and 3% H2SO4 of the oil weight and heated until the temperature reaches 60°C. Subsequently, transesterification process was completed by reacting Philippine Tung oil with methanol and NaOH catalyst of which NaOH to oil (wt/wt) was at 0.25%, 0.5%, 0.75%, and 1%. The reaction temperature was set up at 60ºC and 70ºC and the molar ratio of methanol-oil was set at 6:1 [11][17]. The transesterification process was conducted in 3 times repetition for each process (**Figure 2**).

Table 1. Properties of Philippine Tung crude oil [18]

No	Properties	Crude oil Philippine Tung	Unit	Methods
1	Acid Number	13.57	Mg KOH/gr	Volumetri
2	Free Fatty Acid	0.21	%	Volumetri
3	Water content	trace	% Vol	ASTM D95
4	Specific Gravity	0.9273	-	ASTM 1298
5	Density at 15 °C	0.9273	gr/ml	Calculated
6	Kinematic Viscosity at 40 °C	64.73	cSt	ASTM D 445
7	Color	Yellow		



R_1, R_2, R_2 = Fatty Acid of Biodiesel Oil

Figure 2. Transesterification reaction of trigliserida (vegetable oil)

Reactants were placed on a hot plate which was then attached to a magnetic stirrer with a speed setting at 325 rpm for 60 minutes. [12]. All the reaction mixture was left overnight to enhance separation (**Figure 3**). Glycerol at the lower part was separated from biodiesel and biodiesel was taken for characterization.

Figure 3. Reactor and separation process

2.2.1. *Specification of reactor*

a. Three neck glassware (Scoott-Duran) 500 mL.
b. Magnetic Stirrer IKA RW20 Digital 70W variable speed.
c. Hot plate barnstead thermolyne
   - Temperature (metric) : Ambient to 540 °C
   - Height (british) : 3.6 in
   - Frequency : 50/60 Hz
   - Width (metric) : 12.7 cm
   - Length (metric) : 25.4 cm

2.2.2. *Analysis method for biodiesel properties*

Yields - the yields was calculated by weight of raw oil before and after reaction using Eq. (1).

Acid number - acid number was calculated using Eq. (2), with the following measurement procedure:

- A 50 ml of the neutralized sprit was put into a conical flask;
- Put in as much as 10 ml of filtered oil to conical flask above ;
- Heat the material to 70 °C, added 3 drops of phenolphthalein solution into the flask to make the first bubbles;
- Titrated the sample using NaOH 0.1 N; and
- The end point of the process was indicated by the presence of a red or pink color.

Density - the pycnometer in an empty state was dried using dry air. After being allowed to stand for 30 minutes, it was weighed. The next step was to fill the pycnometer with the sample and weigh it. Density is the mass of an object divided by its volume in kg/m³ or g/cm³, as calculated by Eq. (3).

Kinematic viscosity - to measure the kinematic viscosity, Ostwald viscometer was used. The procedure was to fill the tube with a sample. Then it was measure the time it takes to move from one position to another.

$$\text{Yield of biodiesel (\%)} = \frac{\text{mass of biodiesel obtained}}{\text{mass of oil used}} \quad (1)$$

$$\text{Acid Value} = \frac{\text{Volume of titrant (ml) x Normality of KOH (N) x 56.1}}{\text{(weight of sample (g)}} \quad (2)$$

$$\rho = \frac{\text{mass}}{\text{Volume}} \quad (3)$$

Saponification - the saponification was calculated by determining the base needed to saponify the compound acids and compensate the free acids, as presented in Eq. (4).

$$\text{Saponification Value} = \frac{(A-B)x\ Nx56.1}{W} \quad (4)$$

where,

A = H_2SO_4, for blank, mL
B = H_2SO_4, for sample, mL
W = weight (dry basis), g
N = normality H_2SO_4 solution
56.1 = equivalent weight of KOH

2.3. *Analysis methods*

Analysis of biodiesel was conducted to identify the quality of biodiesel. The main variables consist of biodiesel density, viscosity, acid value. Other variables were also analyzed including saponification value and yield as shown in **Table 2**. Those properties were then contrasted to the Indonesian National Standard of Biodiesel SNI 7182:2015. Properties were defined as mean and standard deviation (SD). Meanwhile, the interaction of each catalyst concentrations and reaction temperatures were compared with the biodiesel properties using multiple comparison analysis.

3. Result and Discussion

3.1. *Effects of catalyst concentration on biodiesel properties*

Catalyst can be defined as a chemical compound to booster the rate of a reaction by lowering the activation energy so that most of the particles have sufficient energy to react. This is done by directing the reacting particles so that the collisions that occur are more likely to react with the reactants so that require less energy to form products. Various catalyst concentrations produced different biodiesel properties with results detailed in **Table 3**. The effect on yield, acid value, saponification value, density, and viscosity were compared and shown in **Table 4**.

Several parameters play an important role in optimizing biodiesel yield, including type of catalyst, molar ratio of methanol and oil, and reaction temperature [9]. A catalyst concentration that is too small will cause a slow reaction and produce lower product yields, while a too much base catalyst concentration is not recommended, because it will cause an accumulation reaction during the transesterification process [17].

As shown in **Table 3**, yield produced by different concentrations of NaOH were nearly similar. NaOH catalyst at 1% concentration produced the highest yield among concentrations of NaOH catalyst studied. However, multiple comparison analysis showed that yield produced by 1% NaOH were only significantly different to 0.25% NaOH (p=0.042). Several studies indicated that raising NaOH congregation may be triggering factor to saponification which result to lower the yield [17][12]. Hartono et al. suggests that the optimum NaOH concentration was 1% [17].

Acid value can be interpreted as the number of free acids accessible in a solution [19]. The acid value of biodiesel affects by various factors, including raw material employed, level of refining, acid catalyst used, and the free fatty acids

Table 2. Experimental parameters

No	Parameters	Unit	Method
1	Yields	%	-
2	Acid Number	Mg KOH/gr	Volumetri
3	Density at 15°C	gr/ml	Calculated
4	Kinematic Viscosity at 40°C	cSt	ASTM D 445
5	Saponification	Mg KOH/gr	ASTM D94

Table 3. Properties of Philippine Tung biodiesel processed by various NaOH catalyst concentrations

Biodisel properties	NaOH Concentration			
	0.25%	0.5%	0.75%	1%
Yield (%)	96.180 + 0.17	96.298 + 0.13	96.348 + 0.17	96.383 + 0.63
Acid Value (mg KOH/g)	0.466 + 0.009	0.48 + 0.005	0.469 + 0.113	0.491 + 0.006
Saponification Value (mg KOH/g)	200.083 + 0.378	201.370 + 0.453	200.904 + 0.802	201.529 + 0.399
Density (g/mL)	0.889 + 0.003	0.876 + 0.005	0.881 + 0.006	0.875 + 0.012
Viscosity (cSt)	5.276 + 0.391	6.784 + 0.317	6.943 + 0.131	7.069 + 0.12

Table 4. Multiple comparison analysis of NaOH concentrations and biodiesel properties

Biodiesel Properties	NaOH Catalyst Concentration (%)	NaOH Catalyst Concentration (%)	Mean Difference	Lower	Upper	P value
Yield	0.25	0.5	-0.11833	-0.31572	0.07905	0.354
		0.75	-0.16833	-0.36572	0.02905	0.110
		1	-0.20333*	-0.40072	0.00595	0.042
	0.5	0.75	-0.05	-0.24739	0.14739	0.889
		1	-0.085	-0.28239	0.11239	0.624
	0.75	1	-0.035	-0.23239	0.16239	0.958
Acid Value	0.25	0.5	-0.01433*	-0.01806	-0.01061	0.000
		0.75	-0.00333	-0.00706	0.00039	0.089
		1	-0.02533*	-0.02906	-0.02161	0.000
	0.5	0.75	0.01100*	0.00727	0.01473	0.000
		1	-0.01100*	-0.01473	-0.00727	0.000
	0.75	1	-0.02200*	-0.02573	-0.01827	0.000
Saponification Value	0.25	0.5	-1.28750*	-1.29255	-1.28245	0.000
		0.75	-0.82117*	-0.82622	-0.81612	0.000
		1	-1.44667*	-1.45172	-1.44162	0.000
	0.5	0.75	0.46633*	0.46128	0.47138	0.000
		1	-0.15917*	-0.16422	-0.15412	0.000
	0.75	1	-0.62550*	-0.63055	-0.62045	0.000
Density	0.25	0.5	0.01367*	0.0063	0.02103	0.000
		0.75	0.00783*	0.00047	0.0152	0.035
		1	0.01400*	0.00663	0.02137	0.000
	0.5	0.75	-0.00583	-0.0132	0.00153	0.150
		1	0.00033	-0.00703	0.0077	0.999
	0.75	1	0.00617	-0.0012	0.01353	0.120
Viscosity	0.25	0.5	-1.47183*	-2.13463	-0.80904	0.000
		0.75	-1.66683*	-2.27932	-1.05435	0.000
		1	-1.79217*	-2.4058	-1.17853	0.000
	0.5	0.75	-0.195	-0.6913	0.3013	0.673
		1	-0.32033	-0.81686	0.17619	0.244
	0.75	1	-0.12533	-0.3578	0.10713	0.464

*mean difference is significant at 0.05 level

produced during the production process [20]. The acid value declined through trans-esterification process because of alteration of the free fatty acid to be FAME [12]. Among NaOH catalyst concentrations investigated in this study, 1% NaOH resulted in the highest acid number of 0.491 mg KOH/g (p=0.000). NaOH concentration of 0.5% produced higher acid number than 0.25% (p=0.000) and 0.75% (p=0.000) NaOH. The values produced by 0.25% and 0.75% NaOH were not significantly different (p=0.089). High acid value is not good for storage. The longer the storage time, the more the acid value of biodiesel is stored [21]. High acid value was associated with corrosion and deposits in engine [20]-[22]. Furthermore, high acid value could reduce the life span of pumps and filters. Increase in acid value occurs due to oil hydrolysis reaction

The highest saponification value was obtained from the reaction using 1% NaOH and followed by 0.5%, 0.75%, and 0.25% NaOH concentration, respectively. From the multiple comparison analysis, it is known that there were significant differences between all the groups (p=0.000 for all comparisons). Saponification value is a number that shows the amount of KOH required to form a soap of biodiesel. It represents the character of fatty acid exist in the triglyceride. In this case, there will be KOH and methyl esters reacted among them. This parameter is quantity the mean of relative molecular mass of all fatty acids exist in biodiesel. The greater the quantity of saponification values, the smaller the fatty acids and the better the quality of the oil. On the other hand, if the saponification value is small, the fatty acids are large and the quality decreases [23].

Density is the volumetric mass density which is the mass per unit volume. Since the injection system in an automotive engine is volume-based, the mass of fuel injected per engine combustion cycle relies upon its density. Kannan et al. [24] stated that the mass of fuel injected into the automotive engine will be higher with a higher fuel density. Biodiesel density is higher than of diesel fuel and it relies upon its composition. Biodiesel density will be reduced by raising molecular weight and the long carbon chain, meanwhile, it will be increased by increasing degree of unsaturation [24]. It was found that the 0.25% NaOH catalyst produced the highest density and showed significant difference when compared to other concentrations (vs 0.5% p=0.000; vs 0.75% p=0.035, vs 0.1% p = 0.000). However, the densities produced by other concentrations were not statistically different to each other. The study shows that the higher the catalyst put on, the lessened the density. This is caused by the cessation of the glycerol chain [25].

Viscosity is a significant characteristic which indicates the extent of the resistivity of fluid to flow because of the resistance of the fluid when moves over another. The higher viscosity of the fuel will affect on the lengthy of fuel spraying, narrowing spray, and low quality atomization. Nevertheless, the lesser viscosity of the fuel will increase engine and emission performance [26]-[27]. NaOH concentration of 0.25% produced the lowest viscosity of 5.276 mm^2/s and was significantly different compared to other concentrations (p=0.000). Meanwhile, 0.5%, 0.75%, and 1% resulted in not significantly different viscosity properties. The transesterification brings about a decline in the viscosity value of triglycerides used. This is a result of the reduction in the molecular weight of the triglycerides converted to methyl ester [11].

3.2. *Effects of temperature on biodiesel properties*

From the analysis, we found that reaction temperature has an effect on biodiesel properties as shown in **Table 5**. Catalyst concentration also has a significance part in the reaction process. Association of temperature and catalyst concentration with biodiesel properties is presented in **Figure 4**.

Reaction temperature of 60 °C produced a higher yield than the temperature of 70 °C. Leung et al. [28] stated that the higher reaction temperature will be decreasing the viscosity of the oil so that the reaction rate will be increasing. Increasing the reaction temperature can also increase the number of effective collisions to produce reactions so that the biodiesel produced also increases. However, at 70 °C, the yield of biodiesel will be decreasing. This is because it was higher than the boiling point of methanol, which resulted in some methanol experiencing a phase change from liquid to gas. The reduced amount of methanol in the liquid phase in the solution causes a reduction in the number of effective collisions to produce biodiesel so that the biodiesel yield will be reduced [29]-[30]. Nevertheless, to low temperature can also cause catalyst not be actuated yet causing the rate of the molecular reaction and the quantity of collisions decrease as a result the reaction became slow [31]-[32]. The higher the catalyst content in the solution, the lower the energy needed of a reaction, so that the resulting product will be higher [29]. However, if the catalyst concentration increases by more than 1%, the biodiesel yield will continue to decline. This occurs because the addition of excessive catalyst concentrations encourages the reaction to form soap [30]-[33].

Biodiesel produced at 70 °C with 0.25%, 0.75%, and 1% NaOH catalyst had lower acid numbers than the products processed at 60 °C reaction

Table 5. Properties of Philippine Tung biodiesel processed by various reaction temperatures

Biodiesel Properties	Reaction Temperature		P value
	60 °C	70 °C	
Yield (%)	96.344 + 0.078	96.261 + 0.166	0.081
Acid Value (mg KOH/g)	0.483 + 0.009	0.470 + 0.125	0.000
Saponification Value (mg KOH/g)	201.436 + 0.615	200.508 + 0.605	0.000
Viscosity (cSt)	6.499 + 0.668	6.519 + 0.903	0.822
Density (g/mL)	0.885 + 0.006	0.876 + 0.009	0.000

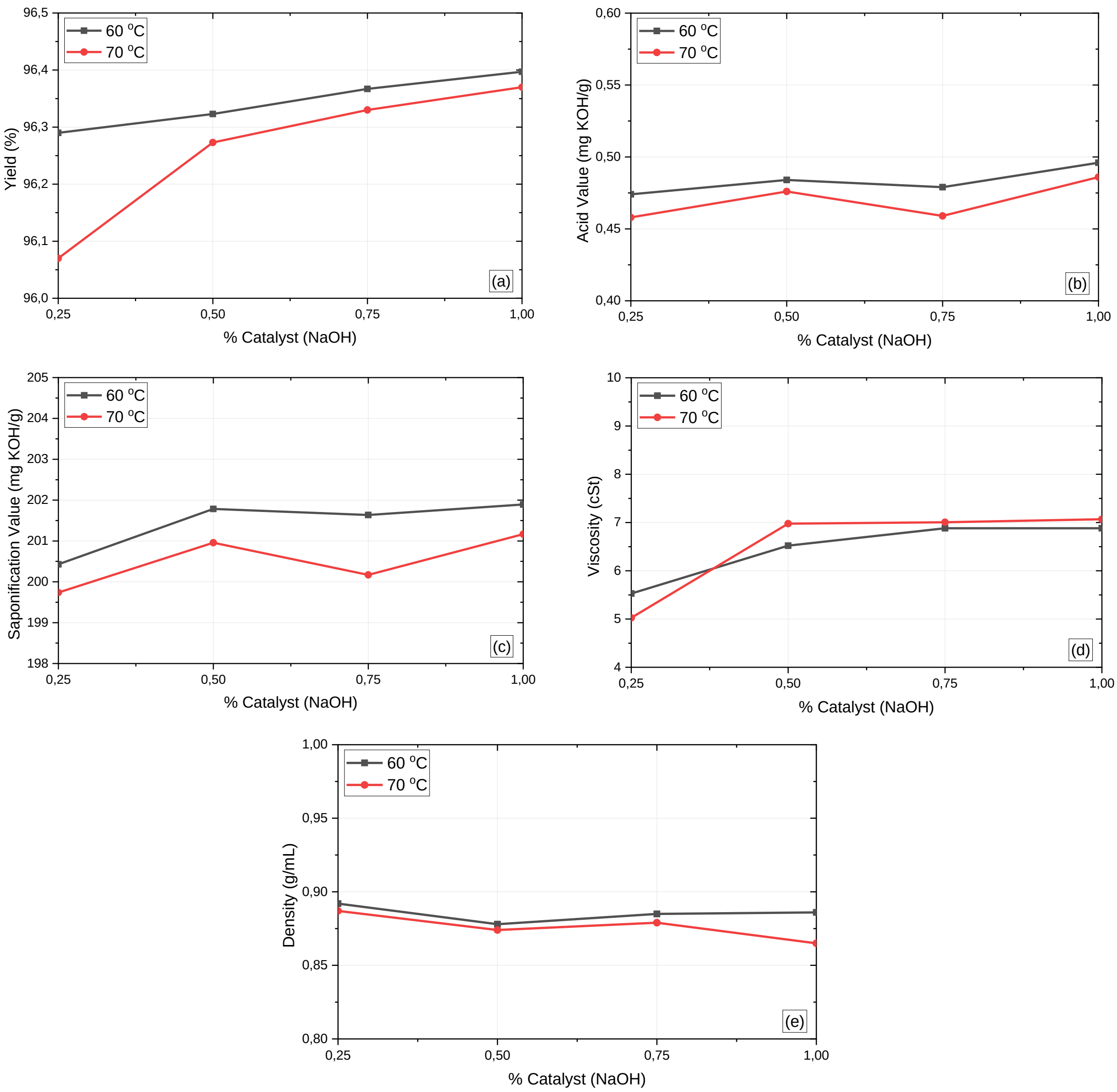


Figure 4. NaOH catalyst concentrations and reaction temperatures against biodiesel yields: (a) yield; (b) acid value; (c) saponification value; (d) viscosity; and (e) density

temperature. Meanwhile 0.5% NaOH catalyst produced an acid value that was not significantly different in both temperatures. Acid value was in the range of 0.458–0.496 mg KOH/g. It showed better results than the results obtained by Nurjanah et al. [12] at 1.76 mg KOH/g, Widyasanti et al [11] at 0.862 mg KOH/gr, and Anggraini [7] in the range of 0.41–0.56 mgKOH/gr. The acid values produced by both temperature parameters and all catalyst concentrations in this study have met the SNI-04-7182-2015 biodiesel standard of ≤ 0.50 mgKOH/g.

Saponification values produced in this study were associated with NaOH catalyst concentrations and reaction temperatures. Reaction completed with the various concentrations at 60 °C generated a higher saponification value than at 70 °C. A similar conclusion was discovered by Salimon et al [34] that increasing the reaction temperature will increase the saponification value of *Jatropha curcas* seed oil positively or vice versa with maximum saponification at 65 °C chosen as the optimal condition [23]. SNI-04-7182-2015 standard requirement for saponification value is <500 mg KOH/g, therefore saponification value of 199.738 to 201.894 mg KOH/g obtained in this study fulfilled the criteria.

Concentration of 0.25%, 0.5%, and 0.75% NaOH catalyst in both reaction temperatures of 60 °C and 70 °C produced densities that were not significantly different. Meanwhile in the reactions using 1% NaOH catalyst, temperature of 60ºC resulted in a significantly higher density than the reaction temperature of 70 °C. According to SNI 04-7182-2015, the biodiesel density standard ranges from 0.850–0.890 g/ml. The density of Philippine Tung biodiesel produced from the transesterification process with various catalysts and temperatures has different values, but still meets the quality requirements of biodiesel. Density values that exceed the provisions of the biodiesel standard requirements will increase engine deterioration, higher emission and wreckage engine parts [22]. High density will also increase the viscosity which consequently will increase the resistance of the fuel flow [35].

Viscosity of biodiesel produced at 60 °C and 70 °C temperatures were not significantly different. The standard kinematic viscosity of biodiesel according to SNI 04-7182-2015 is 2.6–6.0 mm^2/s. The results showed that only 0.25% NaOH catalyst produced biodiesel meeting the criteria. Viscosity relates to the fatty acid composition and purity level of biodiesel [14]. Viscosity raises with raising carbon chain length of saturated fatty acid, increasing carbon chain length of alcohol, decreasing carbon chain length of unsaturated fatty acids, and increasing residual mono, di and triglycerides in biodiesel [27]. Viscosity is also influenced by the degree of polymerization as a result of the oxidation degradation process [28].

4. Conclusion

Crude Philippine Tung oil can be processed into biodiesel using various catalyst concentrations and reaction temperatures, eventually affecting the biodiesel product properties. Concentrations of catalyst significantly influence the yield, acid value, saponification value, density, and viscosity of biodiesel. While reaction temperatures have no effect on biodiesel yield and viscosity. The optimum Philippine Tung biodiesel meeting the requirements of SNI-04-7182-2015 biodiesel standard can be produced using 0.25% NaOH catalyst (yield: 96.18%, acid value: 0.466 mg KOH/g, saponification value: 200.083 mg KOH/g, density: 0.889 g/mL, viscosity: 5.276 cSt). Hence, Philippine Tung shows promising potential as biodiesel feedstock in the future.

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Author's Declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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The authors declare no competing interest.

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