The Effect of Use Microwave Irradiation in Produce Biodiesel Nyamplung Oil (Calophyllum inophyllum Linn) Using KOH Catalyst

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Abstract. Nyamplung (Calophyllum inophyllum Linn) is a non edible that has the potential to produce high yield biodiesel. Oil nyamplung in this study had amounted to 27,498% FFA content, therefore, needs a pretreatment process consisting of degumming to remove gum, esterification and neutralization to lower FFA <2% so that the oil can be resumed in the transesterification process. The purpose of this research to study the effect of microwave power, time and temperature of the reaction to yield biodiesel, identify methyl ester in the product and assess the kinetics of making biodiesel from oil nyamplung using microwave irradiation. Transesterification is done by using a variation of power (100, 200 and 400W), variations of time (5, 7, 10, 12 and 15 minutes) and variations of temperature (50, 55, 60, 65 and 70 °C). The results showed the best conditions using microwave power of 200 W at 65 ° C for 5 minutes, maximum yield of 84.62% biodiesel and biodiesel physical properties meet the standard of SNI 04-7182-2006. GCMS analysis showed that the methyl ester of biodiesel oil nyamplung is 30.23% methyl oleic, 25.76% methyl linoleated, 19.21% methyl palmitate, 15.75% methyl stearic, 2.11% methyl lignocerate, 1.41%, methyl eicosanoic, 0.54% methyl behenate and 0.37% methyl palmitoleic. Transesterification reaction rate constant of first order at a temperature of 55 °C, 65 °C and 70 °C is 0.395 min⁻¹, 0.405 min⁻¹ and 0.412 min⁻¹. Pre exponential factor (A) amounted to 1.0161 L / mol min; the activation energy (Ea) 2579.834 J/mole and the rate of transesterification reaction (r) = 1.0161e^(2579.834/RT)[ME]. The results of this study showed that the rate of reaction using microwave irradiation higher and the reaction time becomes 1/6 times faster with activation energy value is smaller than with conventional methods.

Keywords: biodiesel, microwave, nyamplung oil

1. Introduction
Indonesia still relies heavily on fossil fuels as an energy source. The raw material of biodiesel used in Indonesia is palm oil and castor oil. The use of palm oil as a raw material for biodiesel is considered less efficient because they interfere with food security. While Jatropha oil is still a constraint due to the low productivity of Jatropha. One non-food crop that has the potential to produce biodiesel high randemen is nyamplung (Calophyllum inophyllum Linn). C.inophyllum tree can be planted at a density of 400 tree/ha with an average oil yield of 11.7 kg/tree or 4680 kg/ha [1]. The oil content of Calophyllum inophyllum seed kernel is in the range of 40–73%. It has higher oil yield than Jatropha curcas 40–60% and palm oil 45–70% [2].

Various catalytic reactions that are used in biodiesel production are alkali catalyzed, acid catalyzed and enzymatic transesterifications. Among these catalytic reactions, alkali catalyzed transesterification
provides optimal results at low temperatures and shorter reaction time [3].

Selection of technology for biodiesel manufacturing process is very important because biodiesel is a renewable energy source so that the manufacturing process must pay attention to the efficiency of the process. Microwave radiation is a good method to accelerate the reactions due to direct energy transferred to the reactants so that the heat transfer process is more effective when compared to conventional heating and reaction can be completed in a shorter time [4]. Previous studies have indicated that using microwave-assisted chemical reactions is more efficient than using other synthetic techniques, and that microwave heating systems can increase the reaction rate, product yields and purity of products and reduce the reaction time [3,5].

Methanol is an excellent microwave radiation absorption material because the dipole of methanol reorients, which can destroy the two-tier structure of the interface between methanol and oil, thereby improving the solubility of methanol and oil under microwave radiation and enhancing the transesterification reaction [6].

Calophyllum inophyllum Linn oil containing FFA amounted to 27.498%, therefore it can't be converted directly into biodiesel transesterification reaction conventional with bases catalyst. Two or three-stage method has been applied to produce high quality biodiesel from these raw materials by some researchers. For example, Research produced high viscous (72 mm²/s at 40°C) and high acid value (44 mg KOH/g) Calophyllum inophyllum oil based mono esters (biodiesel) by triple stage transesterification process and blended with diesel in a single cylinder diesel engine [7]. A three step process is acid base process, acid-pretreatment and followed by main base transesterification reaction using methanol as reagent as well as H2SO4 and KOH as catalysts to produce biodiesel from Calophyllum inophyllum oil. Venkanna examined the biodiesel from Calophyllum inophyllum Linn through pretreatment with acid esterification, alkali transesterification and post treatment [8]. SathyaSelvabala conducted a two-stage process to produce biodiesel from Calophyllum inophyllum Linn using solid acid catalysts modified zeolite for the pretreatment step is followed by a transesterification reaction using KOH catalyst [9].

Suppalakpanya concluded that the optimal reaction parameters for the transesterification process aided by microwave heating are a molar ratio of palm oil to ethanol of 1:8.5, 1.5 wt% KOH/oil, a reaction time of 5 min, and a microwave power of 70 W [5]. Ridho concluded that a 1:9 oil to methanol ratio, 4 wt% CaO for 100W microwave heating achieving a biodiesel yield of 94% and properties of biodiesel has met the standard of SNI 04-7182-2006 [10]. Antonius Prihanto regarding the manufacture of biodiesel from oil nyamplung through esterification—neutralization—transesterification process (E-N-T) to produce biodiesel yield higher than esterification-transesterification process (E-T). The best conditions of making biodiesel from oil nyamplung through E-N-T on a methanol-oil molar ratio of 8: 1, the catalyst concentration of 1,25 wt% KOH at 60 °C with a yield biodiesel of 92.20% [11].

Study of the first order reaction kinetics in batch reactor by Sahirman showed that the rate constant of the transesterification reaction at a temperature of 302K, 318K, 333K and 343K respectively 0.0546 min, min 0.0663, 0.1174 minutes. The activation energy of 3870.5 cal / mol and a transesterification reaction rate (r) = 32,23e (3870.5 / RT) [ME] [12]. First order reaction kinetics are also used by Kafuku , which examines biodiesel from oil Croton megalocarpus; Jain S. et al and Shah KA. et al examines biodiesel from used cooking oil [14,15] and Nautiyal examines biodiesel from microalgae Spirulina plantesis [16].

Novelty in this research is the study of reaction kinetics of transesterification of making biodiesel from oil nyamplung using microwave irradiation to be compared with conventional methods. The hypothesis of this study is the use of microwave irradiation can improving the rate of reaction with activation energy value is smaller than with conventional methods.

2. Materials and Methods
2.1. Materials
The materials used in this study is nyamplung oil (Calophyllum inophyllum Linn) of Koperasi Jarak Lestari Cilacap, Central Java, KOH pa (Merck), H2C2O4.2H2O extrapure (Merck), H2SO4 pa,
H3PO4 pa and CH3COOH pa and 96% ethanol. The equipment used in this study were microwaved brand Elektrolux models MM820AYC-PA0C EMM2007X type, a series of transesterification reactors, vacuum oven brands MTI model of EQ-6020-FP, GC (Gas Chromatography) brands Hewlett Packard 5890 Series II and Shimadzu GCMS-QP2010S.

Fig. 1. The series of experimental tools

Caption:
1) Reactor
2) Microwave
3) Power control
4) Time control
5) Reflux condenser
6) The cooling water flow in
7) The cooling water flow out
8) Magnetic stirrer
9) Temperature control

2.2. Methods
2.2.1. Pretreatment
Nyamplung oil of Koperasi Jarak Lestari Cilacap had higher levels of free fatty acid (FFA) of 27.498%, necessitating the pretreatment stage before transesterification. This pretreatment stage consists of degumming which aims to eliminate the gum composed of phosphate, protein, carbohydrate, water residue, resin and impurities and esterification and neutralization stages that aim to reduce levels of FFA and water so as to proceed to the stage of transesterification.

a) Degumming Process
In order to improve the oxidation stability of the final product, the oil is separated from the gums through the degumming process [17]. Nyamplung oil 400 mL heated to a temperature of 80°C then added phosphoric acid as much as 8 mL (2% v/v) nyamplung oil, stirring for 15 minutes. Furthermore, the oil left in the separating funnel to separate dirt from the gum and oil [12].

b) Esterification With An Acid Catalyst
According to Zhang [18] the ratio of oil to methanol effective for the esterification process was 6.82: 1 to 54.55: 1. 300 ml nyamplung oil results degumming heated in a three-neck flask to a temperature of 60 °C was added 6 mL of H2SO4 as a catalyst (2% v/v) and 82 mL of methanol (molar ratio methanol: oil 8: 1) with stirring speed of 400 rpm for 60 min at 60 °C. After going through the heating process, the separation between methanol, oil and water using a separating funnel. Oil formed in the esterification I have a 13.19% FFA esterification II that needs to be done. 300 ml oil esterification I heated to a temperature of 60 °C was added 6 mL of H2SO4...
catalyst (2% v/v) and 42 mL of methanol with stirring speed of 400 rpm for 60 min at 60 °C. Furthermore, the oil is washed with distilled water temperature of 40 °C dried in an oven at a temperature of 105 °C for 20 minutes to reduce the water content [10].

e) Neutralization
250 mL oil esterification II further heated to a temperature of ± 60 °C, added 5 mL 1 N KOH solution (2% v/v) and stirred for 2 minutes. Oil was transferred to a separating funnel and added water temperature of 70 °C ± 10% of the volume of oil and letting the oil and water can be separated. The washing process is repeated until the washing water is neutral, then dried at a temperature of 85 °C with vacuum drying for 30 minutes [11].

2.2.2. Transesterification
a) Transesterification of Conventional Methods
1,874 grams of KOH catalyst (1 wt%) was mixed with 86 mL of methanol in a water bath thermostatic incorporating a magnetic stirrer for 5-10 minutes. 200 mL nyamplung oil introduced into the reactor contains a mixture of catalyst and methanol followed by heating in the transesterification reactor to a temperature of 65 °C. The transesterification process is done with a stirring speed of 400 rpm at a pressure of 1 atm, methanol to oil molar ratio of 8:1 for 30 minutes with sampling every 6 minutes. Subsequently, the mixture is put into a separating funnel and allowed to stand until the layers separate. A layer of biodiesel is washed with warm distilled water and acetic acid to remove the catalyst, methanol and other impurities. Then dried in a vacuum oven for 30 minutes at a temperature of 105 °C to reduce the water content. Transesterification conducted with variations temperature reaction (50, 55, 60, 65 and 70 °C). Data obtained during the concentration of methyl ester transesterification reaction.

b) Transesterification of Microwave Irradiation
200 mL of nyamplung oil added the reactor into microwave. 1,874 grams of KOH catalyst (1 wt%) was dissolved in 86 mL of methanol. The mixture of catalyst and methanol put in a microwave reactor contains nyamplung oil, followed by heating at a temperature of 65 oC. Heating the mixture in the microwave using 100W power for 5 minutes with sampling every 1 minute. Subsequently, the mixture is put into a separating funnel and allowed to stand until the layers separate. A layer of biodiesel is washed with warm distilled water. Then dried in a vacuum oven at a temperature of 105 °C to reduce the water content. Transesterification conducted with stirring speed of 400 rpm at a pressure of 1 atm with a variety of power microwave (100, 200 and 400W), variations in the temperature reaction (50, 55, 60, 65 and 70 °C) and the variation of reaction time (5, 7, 10, 12 and 15 minutes). Data obtained during the concentration of methyl ester transesterification reaction. The method of analysis quality biodiesel The physical properties of biodiesel from nyamplung tested include density, acid number, kinematic viscosity, flash point and calorific value using the standard method ASTM. The determination of the concentration of methyl ester derived from analysis using gas chromatography (GC) Hewlett Packard 5890 Series II using HP-1 non-polar column and a flame ionization detector (FID T300). 0,5μL sample injected with a pressure of 0,75 kPa with He carrier gas flow rate 40mL/ min and injector temperature of 290 °C. Oven temperature starting from 120 °C held for 3 minutes to increase to 8 °C/min to a temperature of 280 °C.

c) Transesterification Reaction Kinetics
Transesterification reaction is assumed to follow the first order kinetics as a function of the concentration of methyl ester (biodiesel) formed during the reaction [19]. Rate equation first order reaction kinetics presented in equation (1):

\[ \frac{d[ME]}{dt} = k[ME] \]  

(1)

Assuming the initial concentration of methyl ester as ME0 at time t=0 and concentration after time t as MEt, the integration of equation (1) can be written as an equation (2):

\[ \ln \left( \frac{[ME]}{[ME0]} \right) = ktor \]  

(2)
The content of methyl esters in biodiesel analyzed using Shimadzu GCMS-QP2010S include Agilent HP 5ms column (30mLx0.25 IDx0.25 μm thick films). Sample injected with He carrier gas flow rate 10ml / min and injector temperature of 300 °C. The temperature of the injection port and detector were set at 300 °C, respectively. The oven temperature was programmed to initiate at 50 °C for 5 min, and then the temperature was raised to 260 °C at a rate of 5 °C/min, and held for 5 min. The injection volume was 0.5μL with a pressure of 12 kPa in the split-less injection mode. The capillary column was a Agilent HP 5MS, 30 m x 0.25 mm ID, and the film thickness was 0.25 μm. The split rate was 1:12. The velocity of carrier gas (He) was set at 26.6 cm/s.

Biodiesel yield is calculated using Equation 3:

\[ \text{yield} = \frac{\text{biodiesel produced (grams)}}{\text{oil used (grams)}} \times 100\% \]  

The activation energy (Ea) and pre exponential factor (A) was calculated using the Arrhenius equation.

3. Results and Discussion

Nyamplung oil pure greenish-black, viscous and foul-smelling. Oil nyamplung in this study had amounted to 27.498% FFA content, therefore, needs a pretreatment process that consists of degumming to remove gum, esterification and neutralization to lower FFA <2% so that the oil can be resumed in the transesterification process.

After degumming oil colors nyamplung turn into reddish yellow. It was due to the loss of chlorophyll natural dye in the oil nyamplung. According Leksono Budi [34] when the crude oil contains FFA> 20%, then the esterification reaction is carried out two stages. First esterification process produces three product layers. The top layer is brown is methanol, the middle layer is a brownish yellow oil with black and the bottom layer is water. Second sterification process produces two layers of products. The top layer is a brown colored oil is black and the bottom layer is water. Decreased levels of FFA and viscosity during the process of treatment are presented in Table 1.

| Stage of Pretreatment | Kadar FFA(%) | Viskosity(mm²/s) |
|-----------------------|-------------|-----------------|
| Nyamplung oil         | 27,498      | 54,088          |
| Degumming             | 25,521      | 43,848          |
| Esterification I      | 13,190      | 40,837          |
| Esterification II     | 5,940       | 28,633          |
| Neutralization        | 1,269       | 11,519          |

Table 1 shows that after degumming, decreased FFA were very small because FFA levels are still high at 25,521%. A decrease in viscosity at degumming process due to the loss of sap and other impurities as degumming process. FFA decreased levels occurred significantly during the esterification process I, II esterification and neutralization. This is because the esterification reaction to convert free fatty acids in the oil reacts with methanol to form methyl ester and water, and the neutralization of free fatty acid reacts with a base so as to be neutral. Decrease in viscosity occurs during esterification and neutralization caused by the heating process is carried out continuously. Oil pretreatment process results brownish yellow with FFA content of 1,269% and has met the requirements of oil to do the transesterification reaction. Biodiesel from nyamplung oil generated in this study is brown clear as the color of tea, unlike biodiesel generally clear yellow. This is because the pretreatment process biodiesel through repeated heating process of degumming, esterification and neutralization which causes the color to dark. Dark colors on oil because some of the heating process that resulted in the destruction of organic compounds and the formation of free radicals that form the polymer.
3.1. Effect of Microwave Power On Yield Biodiesel

Effect of microwave power to the yield biodiesel is presented in Figure 2.

![Fig. 2. Effect of microwave power on yield biodiesel](image)

Figure 2 shows that the biodiesel yield an increase in microwave power of 100 W to 200 W from 74.12% to 84.25% and the decline is not significant at 400 W power becomes 82.46%. This is consistent with research [21,22] which shows that increased microwave power would lead to increased yield of biodiesel. While the decline in the yield of biodiesel at 400 W power due to high temperature in the microwave, causing a portion of the methanol turns into a vapor phase which causes the amount of methanol that react with triglyceride to be reduced. This is consistent with research Patil PD. [23] found that high-power microwaves cause the movement speed of the dipole moment in methanol which can damage the limits methanol and oil thereby reducing the dielectric constant and the polarity of methanol resulting in homogeneity of methanol in the oil. The reaction temperature and microwave heating in this experiment maximum at 70 °C, which means that the microwave irradiation is stopped when the temperature is higher than the specified temperature.

3.2. Effect of Reaction Time On Yield Biodiesel

Effect of reaction time on the yield biodiesel is presented in Figure 3.

![Fig. 3. Effect of reaction time on yield biodiesel](image)

Figure 3 shows biodiesel yield optimum reaction time of 5 minutes, then decreased up to 10 minutes of reaction time and increased insignificantly in the 12th minute and then decreased again in the 15th minute. This shows that the use of microwave for 5 minutes can produce biodiesel yield higher than longer reaction. The longer the reaction time, the yield of biodiesel produced diminishing returns. This phenomenon could be explained by fact that, at initial stages microwave irradiation promoted the thermal accumulation of the reaction mixture which leads to the effective biodiesel production. Thereafter, diffusivity of reaction mixture decreases and hence biodiesel production is reduced. This is consistent with research Eevera T. and Ma, FR which showed that the reaction time excessively will reduce the yield of biodiesel because of side reactions transesterification to the methyl ester will be reduced for the rest of the free fatty acids react with the catalyst forming soap [24,25]. The results of this study indicate that the transesterification reaction using microwave irradiation may
take 1/6 times faster than the transesterification using conventional methods for 30 minutes.

3.3. Effect of Reaction Temperature On Yield Biodiesel

Effect of reaction temperature on the yield biodiesel is presented in Figure 4.

![Fig. 4. Effect of temperature reaction on yield biodiesel](image)

Figure 4 shows the tendency that the higher the temperature, the higher the yield of biodiesel. Increased yield significantly at temperatures of 50 °C to 65 °C temperature from 70,99% to 77,15%, but the yield of biodiesel decreased at 70 °C amounted to 75,26%. The higher temperatures will increase the catalytic activity. This is consistent with research Azcan which states that the biodiesel yield will increase with increasing reaction temperature [26]. The increase in the reaction temperature will reduce the viscosity of the oil due to the solubility of triglycerides in methanol increase with increasing kinetic energy between molecules of triglyceride and methanol, so that the reaction rate increases. Increasing the reaction temperature can increase the number of collisions effective to produce biodiesel [27]. At a temperature of 70 °C decreased the yield of biodiesel because it has passed the boiling point of methanol (64,7 ° C), so some methanol undergo a phase change from liquid to gas. The methanol phase changes cause the amount of methanol in the liquid phase is reduced so that the number of collisions effective for biodiesel yield will be reduced. This is consistent with the results of research [14,27,28] that at a temperature of 70 °C biodiesel yield decreased due to evaporation of methanol and triglyceride saponification reaction accelerated.

3.4. Transesterification Reaction Kinetics

To determine the accuracy of the reaction kinetics model made Graph relationship ln [ME] versus ln d [ME] / dt of equation (1) is presented in Figure 5.
Figure 5 shows that the relationship ln [ME] with ln d[ME]/dt is linear according to equation (2). Equation ln d[ME]/dt = 1.470 ln [ME] -0.630 (R² = 0.993) indicating that the reaction rate varies linearly with the yield of biodiesel. R² value of 0.993 indicates that the first order reaction kinetics model has high accuracy for close to 1. The reaction rate constant (k) at some temperature variations are calculated from equation (2) which states that the temporal plot of time with ln [ME]t / [ME]0 presented in Figure 6:

![Figure 6. Plot of time with ln [ME]t / [ME]0](image)

Figure 6 shows that of the three lines almost coincide, so constant of rate reaction at a temperature of 55, 65 and 70 °C difference is very small. A very small difference is due to the concentration of methyl ester produced at the same time at different temperatures the difference is very small. The reaction rate constant (k) at a temperature of 55 °C, 65 °C and 70 °C, respectively for 0.395 min⁻¹; 0.405 min⁻¹ and 0.412 min⁻¹. In the same way, the result for the reaction rate constant (k) for the conventional method at a temperature of 55 °C, 65 °C and 70 °C, respectively for 0.064 min⁻¹; 0.068 min⁻¹ and 0.069 min⁻¹. This is in accordance with the Arrhenius theory that the higher the temperature, the higher the reaction rate constants. The reaction rate constant prices using microwave irradiation is greater than with conventional methods. This is consistent with research Kumar that the magnitude of the reaction rate constant varies depending on the composition of fatty acids in the oils used, the reaction conditions and technology for the production of biodiesel [29].

Preexponential factor (A) and the activation energy (Ea) was determined by plotting the relationship between ln k with 1/T are presented in Figure 7.

![Figure 7. Plot of ln k with 1/T](image)

By using the Arrhenius equation, then from Figure 7 obtained the activation energy (Ea) of 2579,834 J / mol; collision factor (A) of 1,0161 L / mol min and the rate of the transesterification reaction (rt) = 1,0161e (2579,834 / RT) [ME] for microwave method. Then, in the same way do the calculations for the conventional method and obtained the activation energy (Ea) of 4831,265 J / mol; pre exponential factor (A) of 0.3772 L / mol min and the rate of the transesterification reaction (rt) = 0.3772 e (4831,265 / RT) [ME]. The use of microwave irradiation produces factor greater impact than
conventional methods. This is because the use of microwaves cause the molecules that direct the increased mobility of the increase in pre exponential factor [30]. A decrease in the activation energy in the microwave was associated with an increase in entropy [31]. The increase in entropy as a result of rise in temperature in a closed system in the microwave. The OH group was directly excited by the microwave radiation, causing the local temperature surrounding the OH group to be much higher than that of the environment, which caused the activation energy to considerably exceed the amount required for transesterification [32]. The results showed that the rate of the transesterification reaction using microwave irradiation is greater than the rate of transesterification reaction using conventional methods. This is because the wave microwave irradiation involves dipolar polarization and ionic conduction. Microwave on high frequency cause a phase difference between the field and the orientation of the dipole. Ionic conduction caused by dissolved particles interact under the influence of microwave wave. When the direction of the electric field changes, ion conduction is slow and will convert the kinetic energy into heat energy by friction [6,33].

3.5. Biodiesel Analysis Results

The physical properties of biodiesel nyamplung microwave irradiation compared to standard SNI 04-7182-2006, ASTM 6751-02 and EN-14214 are presented in Table 2.

| Physical properties | Bio-diesel | SNI 04-7182-2006 | ASTM 6751-02 | EN-14214 |
|---------------------|------------|------------------|-------------|---------|
| Density at 40 °C (kg/m³) | 881 | 850-890 | 870-890 | 860-900 |
| Acid value (mg KOH/g) | 0.4910 Maks. | 0.8 Maks. | 0.5 Maks. | 0.5 Maks. |
| Kinematic viscosity at 40°C (mm²/s) | 4,1338 | 2.3-6.0 | 1.9-6.0 | 3.5-5.0 |
| Flash point (°C) | 165 | Min. 100 | Min. 131 | Min. 101 |
| Heat value (BTU/1h) | 15.814 | - | - | - |

Table 2 shows that the physical properties of biodiesel nyamplung with microwave irradiation under test meets the standards of SNI 04-7182-2006, ASTM 6751-02 and EN-14214. GCMS analysis of the results that have been carried out, the obtained methyl ester content of biodiesel oil nyamplung with microwave irradiation, 30.23% methyl oleate, methyl linolelaidat 25.76%, 19.21% methyl palmitic, 15.75%, methyl stearate, 2,11% methyl lignocerate, 1,41% methyl eicosanoic, 0,54% methyl behenate and 0,37% methyl palmitoleic. This is consistent with the analysis Ramaraju [34] that the fatty acids contained in the calophyllum inophyllum oil is 42.7% oleic acid, 17.9% palmitic acid, 13.7% linoleic acid and 8,5% stearic acid, 2,6% lignocerate acid, 2,5% palmitoleic acid and 2,1% linolenic acid.

4. Conclusions

Based on these results it can be concluded that microwave irradiation with KOH catalyst can be used in the process of making biodiesel from oil nyamplung. The maximum yield of as much as 84.62%. The physical properties of biodiesel are tested in compliance with the standard SNI 04-7182-2006, ASTM 6751-02 and EN-14214. GCMS analysis showed that the methyl ester of biodiesel oil
nyamplung is 30.23% methyl oleate, 25.76% methyl linoleaidat, 19.21% methyl palmitate, 15.75% methyl stearate, 2.11% methyl lignocerat, 1.41% eicosanoat methyl, 0.54% methyl behenate and 0.37% methyl palmitoleic. Biodiesel nyamplung with microwave irradiation had a reaction rate constant (k) at a temperature of 55°C, 65°C and 70°C, respectively for 0.395 min⁻¹, 0.405 min⁻¹ and 0.412 min⁻¹, the activation energy (Ea) of 2579.834 J / mol, impact factor (A) of 1.0161 L / mol min, the rate of the transesterification reaction (rt) = 1.0161e^{(2579.834 / RT)} [ME]. While biodiesel nyamplung with the conventional method has the reaction rate constant (k) for the conventional method at a temperature of 55°C, 65°C and 70°C, respectively for 0.064 min⁻¹, 0.068 min⁻¹ and 0.069 min⁻¹; activation energy (Ea) of 4831.265 J / mol, pre exponential factor (A) of 0.3772 L / mol and the rate of the transesterification reaction (rt) = 0.3772 e^{(4831.265 / RT)} [ME]. The results of this study showed that the rate of reaction using microwave irradiation higher and the reaction time becomes 1/6 times faster with activation energy value is smaller than with conventional methods.

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