The study of temperature variation in catalytic biodiesel production process using static mixing reactor

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Abstract. Biodiesel is a renewable fuel commonly used for diesel engines which is made through the transesterification of triglycerides and methanol compounds. The raw materials used in this research are palm oil and methanol (1: 6 mole ratio, oil mole : methanol mole) and the use of 0.5% w/w KOH catalyst. While the treatment carried out there were 2 treatments, namely treatment at the reaction temperature (T1: 30 °C, T2: 45 °C and T3: 60 °C) and the treatment on the tool, namely the sampling point (R5, R7 and R9) using static mixing reactor. The use of 9 reactors in biodiesel production equipment is to determine the effect of using the reactor on the biodiesel yield. The purpose of this research was to obtain the value of acid numbers, saponification numbers, total glycerol, methyl ester content and viscosity. The Results showed that the highest methyl ester content was 99.85% w/w which obtained at the treatment temperature of 60°C at reactor 9.

1. Introduction
Biodiesel is one of the renewable fuels used in diesel engines which is obtained after going through a transesterification reaction process between compounds containing triglycerides and alcohol [1].

There are two methods in the biodiesel production process, namely the catalytic and non-catalytic methods. The catalytic method is a method that requires a catalyst to speed up the reaction between alcohol and triglycerides, while the non-catalytic method does not require a catalyst in the production process [2]. However, the method most often used is the catalytic method because it can be done in one process with a certain duration of time and at a constant temperature [3]. In addition, stirring also affects biodiesel production in a catalytic manner. The stirring process is needed so that the ingredients can mix, collide, and react to produce fatty acid methyl esters [4]. The use of the Static Mixing Reactor in the biodiesel production process aims to obtain a homogeneous mixture of oil and methanol during the transesterification process [5].

One way to increase the frequency of collisions and the rate of reaction other than stirring is the use of temperature. The temperature variations used in the biodiesel production process affect the quality of the biodiesel obtained. The higher the temperature used in the reaction process, then in a shorter reaction the resulting change of glyceride to methyl ester is also higher [6]. So that temperature variations are used using a continuous static mixer system in the biodiesel production process in order to produce methyl esters above the standard of biodiesel (based on SNI), namely 96.50% w/w [7].
2. Materials and methods

2.1. Time and place of research
This research was conducted from June to December 2019 at Biosystem Engineering Laboratory, Agricultural Engineering Study Program, Faculty of Agriculture, Universitas Sumatera Utara. Laboratory analysis was carried out at the Biochemistry/Natural Material Chemistry Laboratory, Chemistry Study Program, Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara.

2.2. Materials and tools
The ingredients used are namely palm cooking oil, methanol and potassium hydroxide pro analysis. Additional material used for washing process is distilled water.

The equipment that used to make biodiesel in this study, namely the continuous system of Static Mixing Reactor, measuring cup, erlenmeyer (250 ml), digital thermometer, pH meter, analytical scale, and drop pipette. The Static Mixing Reactor apparatus used in this study is shown in figure 1.

![Figure 1. Biodiesel production equipment.](image)

Information:
1. Oil tank
2. Methanol tank
3. Oil pump
4. Methanol pump
5. Reactor
6. Static mixer
7. Heater (heater)
8. Digital thermostat
9. Thermocouple
10. Isolators
11. Control Panel

2.3. Research methods
This research used experimental method with two treatments included 3 levels of temperature and 3 sampling points.

The levels of temperature are:
- T1 = at a temperature of 30°C
- T2 = at a temperature of 45°C
- T3 = at a temperature of 60°C

The sampling points are:
- R5 = the 5th reactor
- R7 = the 7th reactor
- R9 = the 9th reactor

The numbers that follow the letters on R5, R7 and R9 lies in the number of reactors through which the material passes. In R5, the materials pass through 5 reactors, as well as R7 and R9.

The biodiesel production process used a static mixing reactor with a continuous system, each material was placed in a separate tank and the production process ran at once. First, the oil was heated according to the required temperature conditions, namely the 1st levels (T1: 30°C), the 2nd (T2: 45°C), and the 3rd (T3: 60°C). Then the catalyst (KOH) was dissolved into methanol so that the resulting solution was more homogeneous, then the process was carried out. Sampling was carried out at R5, R7, and R9.
After obtaining biodiesel, then it would be analysed in the laboratory. Data generated from the laboratory were the value of each parameter, and then analysed using Analysis of Variance (Anova).

2.3.1. Factorial completely randomized design model.

\[ Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk} \]  \hspace{1cm} (1)

Where: \( Y_{ijk} \) is observation results for factor A level-\( i \), factor B level-\( j \), on test k, \( \mu \) is middle value, \( \alpha_i \) is the influence of factor A at level-\( i \), \( \beta_j \) is influence of factor B at level-\( j \), \((\alpha\beta)_{ij}\) is the interaction between A and B at factor A at level-\( i \), factor B at level-\( j \), \( \varepsilon_{ijk} \) is experimental error for factor A level-\( i \), factor B level-\( j \) in group-\( i \).

2.3.2. Calculation of the methyl ester value. In the biodiesel sample, the methyl ester value can be calculated using the following empirical equation:

\[ \text{Kadar ester (\% massa)} = \frac{100(A_s - A_a - 4.57 \times G_{ttl})}{A_s} \]  \hspace{1cm} (2)

Where, \( A_s \) is saponification number (mg KOH/g), \( A_a \) is acid number (mg KOH/g), \( G_{ttl} \) is total glycerol content in biodiesel (\% massa), percentage of methyl ester that meets SNI requirements must be larger than 96.50\% w/w.

3. Results and discussion

3.1. Acid numbers

Figure 2 shows that the lowest acid number obtained at 60°C in R9 is 0.075 mgKOH/g. Meanwhile, the highest acid number was obtained at a temperature of 30°C and 45°C in R9, namely 0.205 mgKOH/g. This occurs due to increase in temperature of the process which can accelerate the reaction.

![Figure 2. Graph of average acid numbers.](image)

3.2. Saponification numbers

Figure 3 shows the highest saponification number in R9 (temperature 60°C), namely 336.6 mgKOH/g. While the lowest saponification number is at 30°C and in the R7, which is 121.5 mgKOH/g.
3.3. Total glycerol content

Figure 4 shows the total glycerol content produced met the biodiesel standard based on SNI 7182-2015 (max. 0.24 %-m). By using the same catalyst (0.5%) and different levels of temperature, the total glycerol yield obtained (Figure 4) shows that the highest total glycerol content is at 30°C in R5 of 0.209 %-m. While the lowest glycerol content was at 60°C in R9 was 0.092 %-m.

3.4. Methyl ester content

Figure 5. Graph of average methyl ester.
Figure 5 shows the highest methyl ester value was obtained in R9 and a temperature of 60°C (99.85 %-m). While the lowest methyl ester content was obtained at a temperature of 30°C in R7 of 99.15 %-m.

3.5. Viscosity
Figure 6 shows the greatest viscosity at 30°C in R7, which is 5.2 cSt. Meanwhile, the lowest viscosity was at 60°C in R7 was 1.9 cSt.

![Graph of average viscosity](image)

4. Conclusions
The results showed the lowest acid number was obtained at temperature of 60°C in R9 with the value of 0.075 mgKOH/g, the highest saponification number was obtained at temperature of 60°C in the R9, namely 336.6 mgKOH/g, the total glycerol content value in biodiesel, the lowest was at temperature of 60°C in R9, which was 0.092 %-m, the highest value of methyl ester was obtained at temperature of 60°C, at R9 which was 99.85 %-m, and the lowest viscosity value was at temperature of 60°C in the R7 was 1.9 cSt.

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Acknowledgements
The research was funded by the Research Central of Universitas Sumatera Utara, Medan for Internal Grand Research (TALENTA 2019 Number: 4167/UN5.1.R/PPM/2019 at April1st2019).