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Analysis of biodiesel yield percentage from used cooking oil with variations in stirring time

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Abstract
The increasing volume of hazardous and toxic waste (B3), particularly from used cooking oil, poses significant environmental and health challenges. One promising solution is converting this waste into biodiesel, thereby promoting renewable energy development while reducing ecological risks. This study investigates the yield percentage of biodiesel produced from waste cooking oil using a magnetic stirrer. The research aims to determine the optimal stirring duration to maximize yield and evaluate the flame duration of the resulting biodiesel. The process involved tool and material preparation, biodiesel production via transesterification, and subsequent data collection and analysis. The findings revealed that the highest biodiesel yield, 58.4%, was achieved at a stirring duration of 45 minutes, whereas the lowest yield, 51.2%, occurred at 60 minutes.

1 Introduction

Energy is a fundamental necessity in modern life, particularly in the transportation and industrial sectors. However, reliance on fossil fuels has led to various problems, such as increased greenhouse gas emissions, environmental pollution, and the depletion of natural resources [1]. Therefore, the search for environmentally friendly and sustainable alternative fuels is becoming increasingly important. One viable solution is biodiesel, which can be derived from vegetable oils as well as waste cooking oil, commonly known as used cooking oil.

In 2006, Indonesia implemented a mandatory policy on renewable energy use, as outlined in Presidential Regulation No. 5 of 2006 on the National Energy Policy. This policy aims to optimize the supply of fuels based on renewable energy sources, including the increased use of biofuels such as biodiesel. The mandatory biodiesel program began in 2008 with a 2.5% biodiesel blend. Over time, the blending ratio gradually increased, and in January 2020, the Ministry of Energy and Mineral Resources officially launched the B30 program, mandating a 30% biodiesel blend with 70% fossil diesel. This progression reflects a growing demand for biodiesel, highlighting the need for ongoing research to improve the quality, productivity, and cost and time efficiency of biodiesel production.

Biodiesel is a type of biofuel that can be produced from vegetable oils or animal fats [2–9]. These feedstocks contain both saturated and unsaturated fatty acids, which affect the quantity or yield percentage of biodiesel produced. One potential raw material for biodiesel production is used cooking oil, which has undergone repeated heating during cooking. Utilizing used cooking oil as a biodiesel feedstock offers dual benefits: it helps reduce waste classified as hazardous and toxic (B3) and provides a more environmentally friendly energy source.

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Used cooking oil, a common domestic and industrial waste product, has strong potential as a biodiesel feedstock. Its use offers several advantages, including waste reduction, lower production costs, and less environmental impact compared to biodiesel derived from virgin vegetable oils [10]. Moreover, converting used cooking oil into biodiesel can help mitigate the environmental problems associated with waste oil disposal, particularly pollution of water and soil [11–13].

The process of producing biodiesel from used cooking oil is typically conducted through transesterification, a chemical reaction between triglycerides in the oil and alcohol (such as methanol or ethanol), facilitated by a catalyst like sodium hydroxide (NaOH) or potassium hydroxide (KOH) [14]. However, high levels of free fatty acids (FFA) in used cooking oil often pose challenges in biodiesel production, as they can lead to soap formation that reduces reaction efficiency [15,16]. Due to repeated heating, used cooking oil contains elevated levels of saturated fatty acids resulting from oxidation and hydrolysis, which can influence both the efficiency of the production process and the quality of the resulting biodiesel. Therefore, the use of used cooking oil as a biodiesel feedstock must be studied in depth to assess its effectiveness and conversion efficiency.

This study aims to analyze the yield percentage of biodiesel produced from used cooking oil using the transesterification method. In addition, the study seeks to evaluate the effect of stirring duration on the yield percentage of the biodiesel obtained. The findings of this research are expected to serve as a reference for optimizing biodiesel production and contribute to the advancement of renewable energy policy in Indonesia, while also helping to mitigate the negative environmental impact of waste cooking oil.

2 Research Methods

This study employed an experimental research method. The results of the study will be presented in the form of a jobsheet outlining the procedure for biodiesel production, designed for use in the Renewable Energy course. The research was conducted in the Energy Conversion Laboratory, Department of Mechanical Engineering, Politeknik Negeri Pontianak.

2.1 Materials

The tools and materials used in this study include: (1) digital scale, (2) test tube, (3) methanol, (4) pH paper, (5) thermometer, (6) used cooking oil, (7) dropper, (8) measuring cylinder, (9) NaOH catalyst, (10) magnetic stirrer, (11) electric stove, (12) distilled water, (13) tachometer, (14) separating funnel, (15) Erlenmeyer flask, and (16) beaker glass.

In this study, the variables were classified into two types: independent variables and dependent variables. The independent variable was the stirring time during the transesterification process, while the dependent variable was the yield percentage of the resulting biodiesel. These variables were clearly defined from the outset to ensure the accuracy and measurability of the results. As is typical in experimental research, the variables both independent and dependent were explicitly determined by the researcher at the beginning of the study as seen as in the Figure 1.

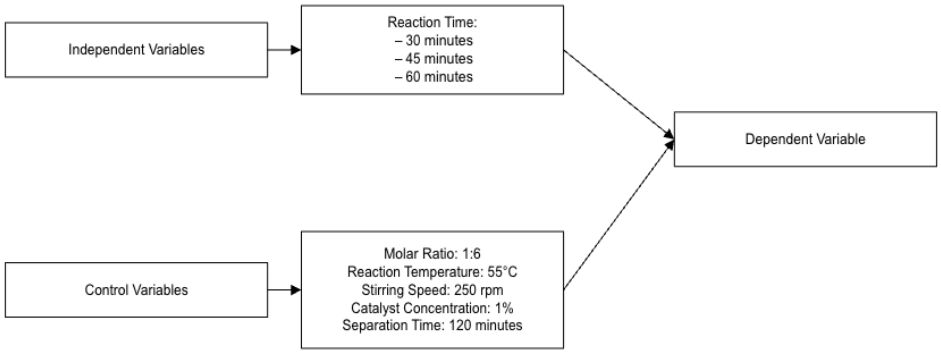

Figure 1. Research Variables

2.2 Procedures

The research procedure consists of several stages (see Figure 2), starting with data collection from the biodiesel production process using waste cooking oil as the raw material through the transesterification method. The biodiesel production process involves five main stages: preparation, transesterification, separation, washing, and drying.

During the preparation stage, the first step involves measuring and preparing the materials and equipment needed for biodiesel production. Procedures at this stage include measuring the volume and weight of waste cooking oil at a molar ratio of 1:6, measuring the volume and weight of methanol using the same ratio, and weighing the NaOH catalyst at 1% of the oil's weight. The NaOH catalyst is then dissolved in methanol to form a homogeneous solution. Weight measurements are taken using a digital scale, while volumes are measured using a measuring cylinder. Before use, the waste cooking oil is filtered by heating and adding potato slices to reduce impurities and produce a cleaner oil.

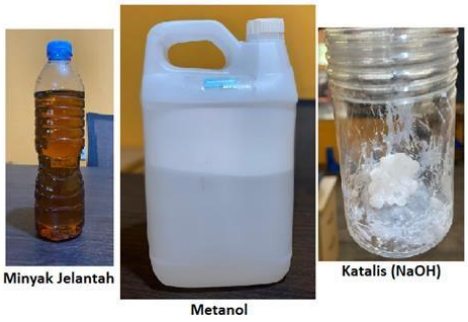

Figure 2. Preparation Stage

In the Figure 3 can be seen that the transesterification stage is the core of biodiesel production, where waste cooking oil is converted into biodiesel through a chemical reaction. The oil is heated to 50°C, then the pre-prepared NaOH and methanol solution is added to the hot oil. The mixture is stirred continuously using a hot plate magnetic stirrer at a speed of 250 rpm and a reaction temperature of 55°C. The reaction time is varied into three groups—30 minutes, 45 minutes, and 60 minutes—to analyze the effect of stirring duration on the biodiesel yield percentage.

Figure 3. Transesterification Process

Following transesterification, the separation stage is conducted to separate the biodiesel from glycerol using a separating funnel. The reaction mixture is placed in the funnel and allowed to sit for 120 minutes, forming two layers: biodiesel (Fatty Acid Methyl Ester/FAME) on the top and glycerol on the bottom. After separation, both biodiesel and glycerol are weighed and their volumes recorded.

Figure 4. Separation Process

The washing stage is carried out to remove residual glycerol and other impurities from the biodiesel. The biodiesel is mixed with distilled water (aquades) at a 1:1 volume ratio and gently shaken to extract the remaining glycerol. Once washing is complete, the water containing impurities is discarded (see in Figure 4 and 5).

Figure 5. Washing Process

Figure 6. Drying Process

In the drying stage (see Figure 6), the biodiesel is heated at 100°C for 5 minutes using an electric stove to ensure all water content is removed from the final product. After heating, the volume and weight of the biodiesel are measured again to determine the final yield. Through these stages, this study aims to analyze the effect of stirring time on the yield percentage of biodiesel produced. Data collected from each stage will be analyzed to evaluate the efficiency of the biodiesel production process using waste cooking oil.

(1)

3 Result and Discussion

The results of this study present detailed data on the weight and volume of FAME (Fatty Acid Methyl Ester) across the separation, washing, and drying stages, to illustrate the changes—either reduction or increase—in the biodiesel obtained. The FAME obtained after the drying process serves as the basis for calculating the yield percentage of the biodiesel. The following are the results from each stage of the process as shown in Figure 7.

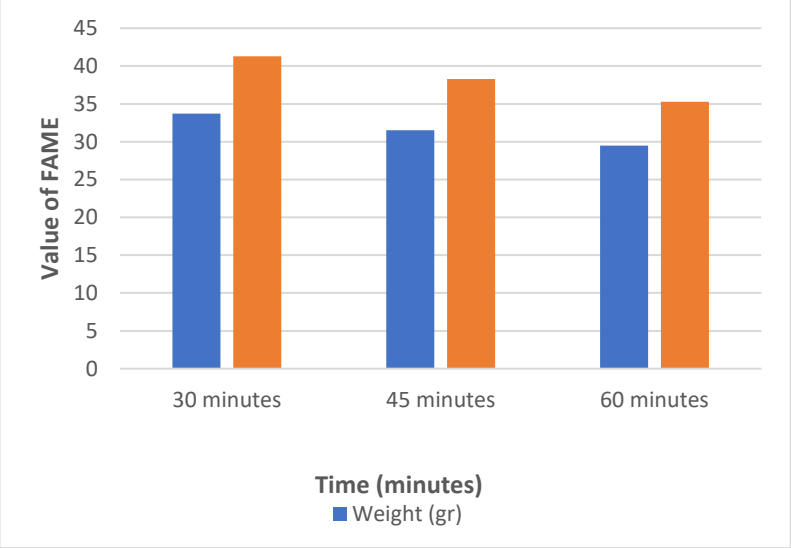

Figure 7. FAME Value in Separation Process

In the separation stage, the data show that the highest weight and volume of FAME were obtained at the 30-minute transesterification time variation (see Figure 8 and 9). The graph illustrates that both the weight and volume of FAME reached their peak at this reaction time. However, residual impurities were still present after separation, making the washing stage essential for further purification.

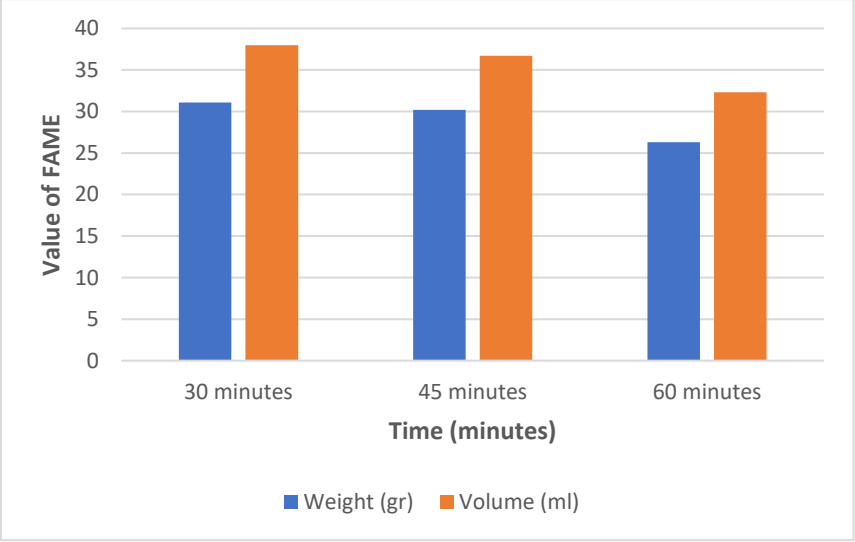

Figure 8. FAME Value in Washing Process

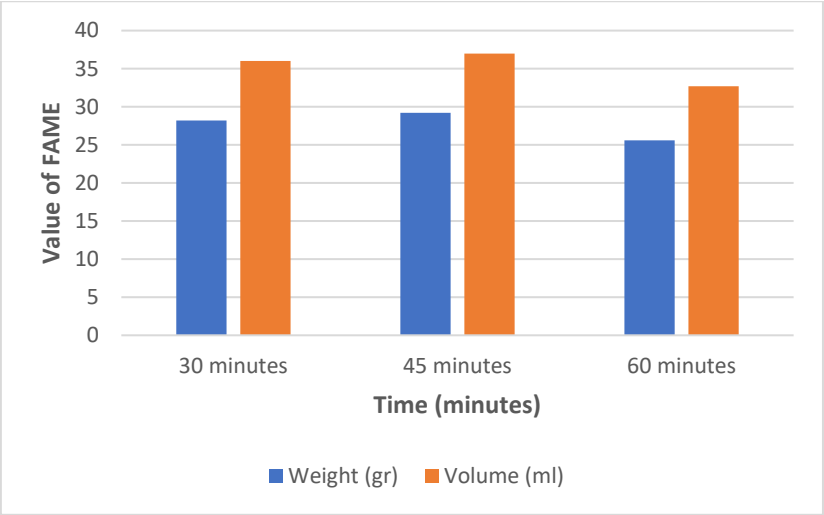

Figure 9. FAME Value in Drying Process

The washing stage also revealed that the highest FAME weight and volume were achieved at the 30-minute transesterification time. The differences in weight and volume across the time variations were not significant, indicating that the washing process was effective in removing remaining glycerol from the biodiesel using distilled water. In the final stage drying the data indicate that the highest FAME weight and volume were obtained at the 45-minute transesterification time. The graph supports this observation, showing that the FAME produced at 45 minutes appeared clearer compared to the samples from 30 and 60 minutes. At 30 minutes, the FAME was more diluted, while the sample from 60 minutes appeared thicker and contained more clumps as shown in Figure 10.

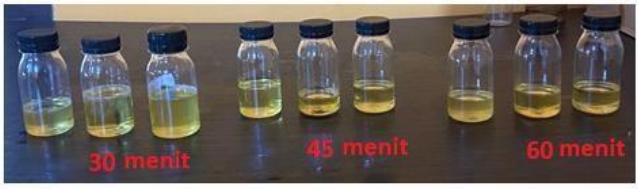

Figure 10. Biodiesel Yield Percentage

The findings of this study indicate that reaction time plays a significant role in determining the quantity and quality of biodiesel produced from used cooking oil. The separation stage showed that the highest FAME weight and volume occurred at the 30-minute reaction time. This suggests that shorter reaction durations can initiate the transesterification process effectively, possibly due to a more stable reaction condition early on. However, at this stage, impurities were still present, highlighting the need for further purification through subsequent processes.

During the washing stage, FAME values remained highest at the 30-minute reaction time, with minimal differences between the tested durations. This indicates that the washing process was consistent in removing residual glycerol and impurities, regardless of how long the transesterification was performed. The use of distilled water (aquades) in a 1:1 volume ratio appears to be effective for this purpose. The consistency in FAME values across all time variations after washing also suggests that this step helps standardize the intermediate biodiesel product before drying.

In contrast, the drying stage revealed a shift in optimum reaction time, with the highest FAME yield obtained at 45 minutes. This suggests that while shorter reaction times may initially produce more FAME, a slightly longer duration allows for better separation of phases and a more complete transesterification process. The visual observations further support this, as FAME at 45 minutes appeared clearer, indicating better quality. In comparison, the 30-minute variation resulted in more diluted biodiesel, while the 60-

minute variant produced thicker FAME with clumping, likely due to soap formation caused by extended reaction time.

Overall, the yield percentage calculated after the drying process confirms that 45 minutes is the optimal reaction time under the set conditions. This aligns with existing studies stating that moderate reaction durations help balance reaction completion with minimal side reactions such as saponification. These findings emphasize the importance of optimizing process parameters not only for maximizing yield but also for ensuring the quality and purity of biodiesel. Thus, the results contribute valuable insights for biodiesel production using waste cooking oil as a sustainable and environmentally friendly feedstock.

4 Conclusion

Based on the results of the study, it can be concluded that biodiesel production using the transesterification method involves five essential stages: preparation, transesterification, separation, washing, and drying. Each of these stages significantly influences both the quality and quantity of the resulting biodiesel. The highest yield percentage, which reached 58.4 percent, was achieved at a transesterification duration of 45 minutes. This finding indicates that optimizing reaction time improves biodiesel output. Although longer durations may lead to changes in the physical characteristics of the product, such as increased viscosity or the formation of soap, a moderate stirring time provides the most effective result.

The novelty of this study lies in its systematic evaluation of FAME weight and volume at each process stage using waste cooking oil as a sustainable and low-cost raw material. The research emphasizes the role of stirring time in maximizing biodiesel yield, a variable that has received less attention compared to catalyst concentration or reaction temperature in previous studies. These findings offer new insights into enhancing biodiesel production efficiency, especially for small-scale operations and educational laboratory settings. This study contributes to the broader effort to promote waste-to-energy solutions and supports the advancement of renewable energy technologies.

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