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The influence of catalyst on the characteristics of biodiesel from waste cooking oil

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Abstract: The aim of this research was to investigate the influence of catalyst on the flash point, viscosity, density, and iodine value of biodiesel. The raw material used in biodiesel production was waste cooking oil. The transesterification process was employed by reacting the catalyst and methanol, followed by mixing them with the waste cooking oil simultaneously. The catalyst concentration variations used in this study were 0.25% and 0.5%. The resulting transesterification mixture was left to settle for approximately 10 minutes. The biodiesel and glycerol were separated after settling, and the biodiesel was washed with distilled water at a temperature of 50°C and then evaporated at 100°C. The flash point test results for catalyst concentrations of 0.25% and 0.5% were 58°C and 48.5°C, respectively. The viscosity test results for catalyst concentrations of 0.25% and 0.5% were 4.567 x 10-6 m^2/s and 4.625 x 10-6 m^2/s, respectively. The density test results for catalyst concentrations of 0.25% and 0.5% were 889 kg/m^3 and 888.3 kg/m^3, respectively. The iodine value test results for catalyst concentrations of 0.25% and 0.5% were 112.2 g I2/100g and 114 g I2/100g, respectively. Based on the test data, the flash point, viscosity, density, and iodine value were obtained. The test results indicated that the flash point values from both experiments did not meet the biodiesel quality standards. However, the viscosity and density test results from both experiments met the biodiesel quality standards and were suitable for use. Regarding the iodine value test, the characteristics of the biodiesel from both experiments did not fully meet the biodiesel standard, although the results obtained were not significantly different from the quality standards set by the Ministry of Energy and Mineral Resources.

Keywords: Biodiesel; sodium hydroxide catalyst; waste cooking oil

1. INTRODUCTION

The world, including Indonesia, is experiencing a rise in energy demand as a result of population growth and economic progress. This surge in demand has put a strain on the available energy resources, with petroleum reserves being particularly limited in specific regions. Furthermore, these reserves are depleting at an alarming rate due to their rapid utilization [1]. The depletion of petroleum reserves has necessitated the exploration of alternative energy sources, and one notable option is biodiesel. Biodiesel is derived from organic matter, such as vegetable oils or animal fats, and can serve as a renewable substitute for conventional petroleum-based fuels. Its production and use offer several advantages, including reduced greenhouse gas emissions, increased energy security, and potential economic benefits. In response to the challenges posed by dwindling petroleum reserves, many countries, including Indonesia, have been actively promoting the development and adoption of biodiesel as a viable energy alternative. Government initiatives and incentives have encouraged research, investment, and infrastructure development in the biodiesel sector. The emergence of biodiesel as an alternative energy source showcases the global shift towards sustainable and environmentally friendly solutions [2], [3]. By embracing biodiesel, countries can reduce their dependence on finite petroleum reserves while simultaneously contributing to a greener and more sustainable future. However, despite its potential, there are still obstacles to overcome in terms of scaling up biodiesel production, ensuring its cost-effectiveness, and addressing potential environmental concerns related to land use and the sourcing of feedstock [4]–[6]. Nonetheless, ongoing advancements in technology and continued investment in research and development hold promising prospects for further improving the efficiency and sustainability of biodiesel production [7], [8].

The escalating utilization of non-renewable petroleum has presented a pressing challenge that requires proactive measures to address. Petroleum, being a non-renewable energy source, undergoes a lengthy process spanning millions, if not hundreds of millions, of years to transform organic matter into the valuable resource. However, the ever-increasing demand for energy has led to the rapid depletion of petroleum reserves, exacerbating concerns regarding its long-term availability. The depletion of petroleum reserves has far-reaching implications for energy security and sustainability. As the global population continues to grow and economies thrive, the reliance on petroleum as a primary energy source becomes unsustainable. The finite nature of petroleum reserves necessitates the exploration and adoption of renewable alternative energy sources to mitigate the impending energy crisis [9].

To ensure a more secure and sustainable energy future, considerable efforts are underway to develop and implement various renewable energy alternatives [10]. These alternatives, such as solar power, wind energy, hydroelectric power, and biofuels, offer promising prospects for meeting the increasing energy demands while minimizing environmental impact. By diversifying the energy mix and reducing dependence on petroleum, societies can transition towards a more sustainable and resilient energy infrastructure. Such a transition requires collaborative efforts from governments, industries, and individuals to invest in research, innovation, and infrastructure development for renewable energy sources [11].

Biodiesel, a diesel fuel substitute, is derived from vegetable or animal oils through transesterification or esterification reactions [12]–[14]. It is classified as a fatty acid ester and possesses significant potential as an alternative to conventional diesel fuel. Biodiesel's viability stems from its production process, which utilizes renewable sources like vegetable and animal oils, allowing for periodic production and easy accessibility [15], [16]. Moreover, biodiesel offers the advantage of relative price stability compared to its petroleum-based counterpart. The production of biodiesel involves chemically transforming vegetable or animal oils into a usable fuel through transesterification or esterification reactions. These reactions break down the oil's triglycerides, resulting in the formation of biodiesel and glycerol as a byproduct. Biodiesel exhibits similar properties to petroleum diesel, making it compatible with existing diesel engines and infrastructure [17], [18].

The renewable nature of the feedstock used in biodiesel production is a key advantage. As vegetable and animal oils are continually replenished through agricultural activities, biodiesel can be produced on an ongoing basis [19], [20]. This ensures a steady supply and reduces reliance on finite fossil fuel resources. Furthermore, biodiesel's relative price stability contributes to its feasibility as a diesel fuel substitute. While petroleum diesel prices are influenced by various factors, including global oil markets and geopolitical events, the cost of biodiesel is relatively more stable due to its dependence on domestically available feedstock and local production. This stability provides economic predictability for consumers and reduces vulnerability to oil price fluctuations [21], [22].

The utilization of diesel engines can result in adverse environmental and human health impacts, primarily attributed to the exhaust emissions emitted by petroleum diesel engines. These emissions contribute to the escalation of air pollution, which poses significant challenges to the environment and public well-being [23]–[25]. To address this concern, biodiesel emerges as the most promising current solution, as it is derived from various vegetable and animal oil feedstocks and offers substantial potential in reducing environmental air pollution [26], [27]. Petroleum diesel engines release a combination of harmful pollutants into the atmosphere, including nitrogen oxides (NO_x), particulate matter (PM), carbon monoxide (CO), and unburned hydrocarbons. These pollutants have been linked to numerous environmental and health issues, such as smog formation, respiratory diseases, and adverse effects on ecosystems. As the use of diesel engines continues to grow worldwide, the need for cleaner and more sustainable alternatives becomes imperative [28], [29].

Biodiesel, being derived from renewable sources like vegetable oils and animal fats, offers a significant advantage in reducing the escalation of environmental air pollution [30]–[32]. When compared to petroleum diesel, biodiesel exhibits lower emissions of harmful pollutants, particularly in terms of sulfur dioxide (SO_2), PM, and unburned hydrocarbons. Additionally, biodiesel combustion produces reduced levels of carbon dioxide (CO_2), a major greenhouse gas contributing to climate change. The widespread adoption of biodiesel as an alternative fuel can lead to substantial reductions in harmful emissions and their associated environmental and health impacts [33], [34]. By utilizing biodiesel in diesel engines, the release of pollutants can be significantly minimized, mitigating the adverse effects on air quality and human health. Furthermore, the use of renewable feedstocks in biodiesel production contributes to the overall reduction of greenhouse gas emissions, promoting a more sustainable and greener energy sector [35].

The goals of this study are to ascertain the relationship between catalyst concentration and the iodine number of bio-diesel, as well as the effects of catalyst concentration on biodiesel's viscosity and flash point value. The overall goal of these study goals is to gain a deeper understanding of the relationship between the concentration of the catalyst and the flash point, viscosity, and iodine number of bio-diesel. Researchers can help to improve the biodiesel production process and guarantee adherence to quality requirements by performing thorough investigations.

2. METHOD

The difference between used cooking oil and fresh vegetable oil lies in the composition of saturated and unsaturated fatty acids. Used cooking oil has a higher content of saturated fatty acids compared to fresh vegetable oil. Transesterification is a reaction that produces esters, where one of the reactants is also an ester compound. It involves the cleavage of triglyceride compounds and the migration of alkyl groups between ester compounds. The ester produced from the transesterification reaction is called biodiesel. Methanol is the simplest form of alcohol. Under atmospheric conditions, methanol is a light, volatile, colorless liquid that is easily combustible and has a distinctive odor. Methanol is the preferred alcohol in biodiesel production because it offers the advantage of being more reactive and stable compared to ethanol. A catalyst is a substance used to accelerate the rate of a reaction and lower the activation energy, but it remains unchanged and does not get consumed in the process. In a chemical reaction, a catalyst does not undergo a permanent reaction and is considered to be non-reactive. Biodiesel is an alternative fuel that replaces diesel oil and is produced from vegetable oil or animal fat. The effectiveness of biodiesel production techniques relies on the production meeting the specified standards and quality requirements applicable in the biodiesel market area.

Flash point is the lowest temperature at which a fuel can ignite and combust when exposed to air. A very high flash point can lead to detonation, which is a small explosion that occurs before the fuel enters the combustion chamber. This can increase the risk of hazards during storage. Viscosity is a property that indicates a fluid's resistance to flow due to internal friction when it moves from one place to another. It affects the atomization of fuel during injection into the combustion chamber, which can result in the formation of deposits in the engine.

Viscosity is a property that indicates a fluid's resistance to flow due to internal friction when it moves from one place to another. It affects the atomization of fuel during injection into the combustion chamber, which can result in the formation of deposits in the engine. The viscosity value is calculated using Equation 1. Where K is the spherical constant of the ball (0.0084 mPa.s.cm^3/g.s), t is the time of fall(s), is ρ_b the density of the ball (kg/m^3) and the density of biodiesel ((kg/m^3ρ_bd). Density, or mass density, indicates the ratio of mass per unit volume. This characteristic is related to the calorific value and power generated by a diesel engine per unit volume of fuel. The density value is calculated using Equation 2. Where m represents the mass of biodiesel (kg), v is the volume (m^3). The level of unsaturation or the number of double bonds in the fatty acid constituents of biodiesel is indicated by the iodine value. The iodine value is calculated using Equation 3. Where B is the number of $Na_2S_2O_3$ 0.1 N used in blank titration, S is the amount of 0.1 N $Na_2S_2O_3$ used in sample titration, N is the Normality of 0.1 N $Na_2S_2O_3$ solution after standardization, G is the sample weight, and 12.69 is the atomic weight of iodine.

$$\mu_{bd} = \mathrm{Kt}(\rho_b - \rho_{bd}) \quad (1)$$

$$(\rho_{bd}) = \frac{m}{v} \quad (2)$$

$$\text{Iodine number} = \frac{(B-S)xNx12.69}{G} \quad (3)$$

This research procedure begins with a literature study, equipment and material preparation, and the experimentation phase of biodiesel production. Subsequently, the resulting biodiesel is subjected to testing for flash point, viscosity, density, and iodine value. Furthermore, the collected test data is analyzed to obtain the characteristics of the produced biodiesel. Finally, the analysis results are documented in a report for publication. The research begins by conducting a thorough literature study to gather relevant information on biodiesel and its production process. Subsequently, the necessary equipment and materials are prepared for the biodiesel production experiments, following established methods. After successfully producing biodiesel, the next step involves testing its flash point, viscosity, density, and iodine value. The obtained data from the tests are then carefully analyzed to derive pertinent characteristics of the produced biodiesel. This analysis includes calculations and evaluations based on the conducted tests, as well as discussions on the compliance of the biodiesel with established quality standards. In the final stage, the analysis results and research findings are summarized in a comprehensive research report. The report encompasses a description of the research procedure, the data obtained from the tests, the conducted analysis, and the conclusions drawn from the research findings. The aim of the report is to be published, contributing to knowledge sharing and advancements in the field of biodiesel.

3. RESULTS AND DISCUSSION

After conducting tests on the produced biodiesel, four characteristics of biodiesel were determined, namely flash point, viscosity, density, and iodine value, each with two experimental trials. The results of the biodiesel characterization tests can be seen in **Table 1**. In the flash point test, the lowest temperature at which the biodiesel ignites when exposed to a flame was measured. This parameter is crucial in assessing the safety and handling of biodiesel. Viscosity, on the other hand, indicates the resistance of the biodiesel to flow and is important for evaluating its performance in fuel injection systems. Density, also known as mass per unit volume, provides insights into the compactness and energy content of the biodiesel. Lastly, the iodine value signifies the level of unsaturation or the number of double bonds present in the fatty acid constituents of the biodiesel. This parameter is crucial for assessing the stability and oxidation resistance of biodiesel. By analyzing and comparing the obtained results from the two experimental trials, a comprehensive understanding of the biodiesel's characteristics can be achieved. These findings contribute to the evaluation and potential improvement of biodiesel production processes, as well as its suitability for various applications in the energy sector.

Table 1. Biodiesel characteristics

Flash Point (°C)	Viscosity 10-6(m^2/s)	Density (kgm3)	Iodin % masa
58	4.567	889	112.2
48.5	4.625	888.9	114

The Influence of catalyst on the flash point of biodiesel

In this study, the author employed two types of catalyst compositions in biodiesel production, namely 0.25% NaOH with 0.15 L of methanol, and 0.5% NaOH with 0.2 L of methanol. In the first experiment using 0.25% NaOH and 0.15 L of methanol, a flash point value of 58°C was obtained, while in the second experiment using 0.5% NaOH and 0.2 L of methanol, a flash point value of 48.5°C was obtained. The effect of the catalyst on the flash point can be observed in **Figure 1**.

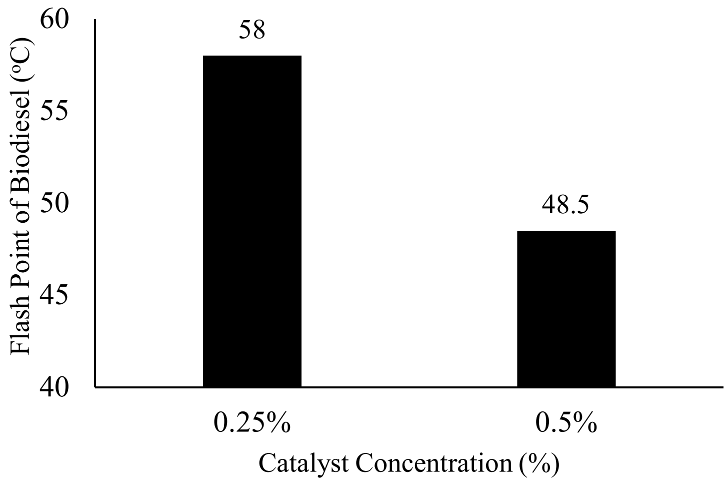

Figure 1. The Influence of catalyst on the flash point of biodiesel

In **Figure 1**, the results of the biodiesel characteristic testing for flash point have been observed. Based on the author's observations, the lower the catalyst concentration, the higher the obtained flash point value. However, the results obtained from both types of biodiesel compositions tested have not yet met the quality standard set by the Ministry of Energy and Mineral Resources (ESDM). The quality standard for biodiesel according to the Ministry of Energy and Mineral Resources is a flash point of 130°C. The author assumes that the obtained results significantly differ from the biodiesel quality standard due to the excessively high concentration of methanol solution. Therefore, the catalyst greatly influences the flash point results of biodiesel.

The influence of catalyst on viscosity in biodiesel

In this research, one temperature variation was used. The author employed two types of catalyst compositions in the biodiesel production, namely 0.25% NaOH with 0.15 L methanol, and 0.5% NaOH with 0.2 L methanol. In the first experiment using 0.25% NaOH and 0.15 L methanol, the viscosity value obtained was 4.567x10-6 m2/s, while in the second experiment using 0.5% NaOH and 0.2 L methanol, the viscosity value obtained was 4.625x10-6 m2/s. The influence of the catalyst on viscosity can be observed in Figure 2

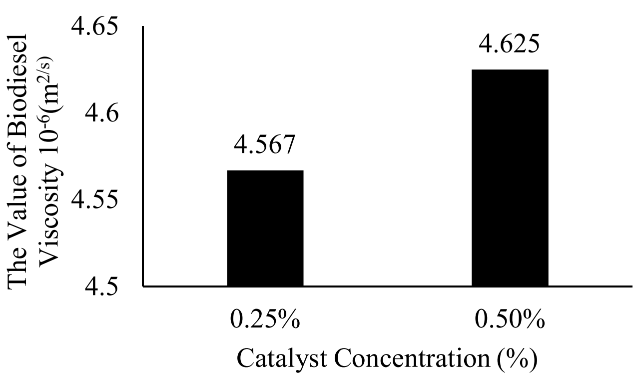

Figure 2. The Influence of catalyst on biodiesel viscosity

In **Figure 2**, the results of the biodiesel characteristics testing for viscosity have been obtained. Based on the author's observation, it is found that the viscosity value increases with higher catalyst concentration. However, both test results still meet the biodiesel quality standard set by the Ministry of Energy and Mineral Resources. The viscosity standard for biodiesel according to the Ministry of Energy and Mineral Resources is 2.3-6.0x10-6 m^2/s. Therefore, the author assumes that the catalyst does not affect the viscosity value of biodiesel.

The influence of catalyst on biodiesel density.

In this study, the authors used two types of catalyst compositions in the manufacture of biodiesel: 0.25% NaOH with 0.15 L of methanol and 0.5% NaOH with 0.2 L of methanol. The first experiment using 0.25% NaOH and 0.15 L of methanol resulted in a density of 889 kg/m3. The second experiment using 0.5% NaOH and 0.2 L of methanol resulted in a density of 888.9 kg/m3. The effect of the catalyst on density can be seen in Figure 3.

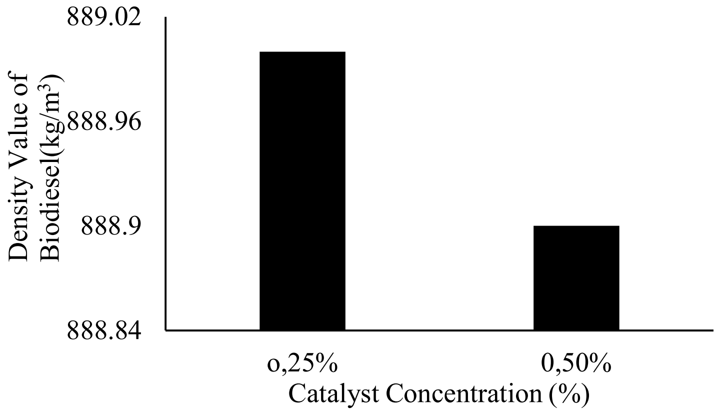

Figure 3. The influence of catalyst on biodiesel density

Figure 3 the results of testing the density characteristics of biodiesel. The author observed that the lower the catalyst concentration, the higher the density value obtained. However, both tests were within the biodiesel quality standard set by the Ministry of Energy and Mineral Resources, which is 850-890 kg/m^3. Therefore, the authors conclude that the catalyst does not affect the density of biodiesel.

The influence of catalyst on iodine number in biodiesel

In this study, the researchers used two types of catalyst compositions to manufacture biodiesel: 0.25% NaOH with 0.15 L of methanol and 0.5% NaOH with 0.2 L of methanol. The first experiment using 0.25% NaOH and 0.15 L of methanol resulted in an iodine number of 112.2 g-l^2/100 g, and the second experiment using 0.5% NaOH and 0.2 L of methanol resulted in an iodine number of 114 g-l^2/100 g. A figure depicting the effect of the catalyst on the iodine number can be found in Figure 4.

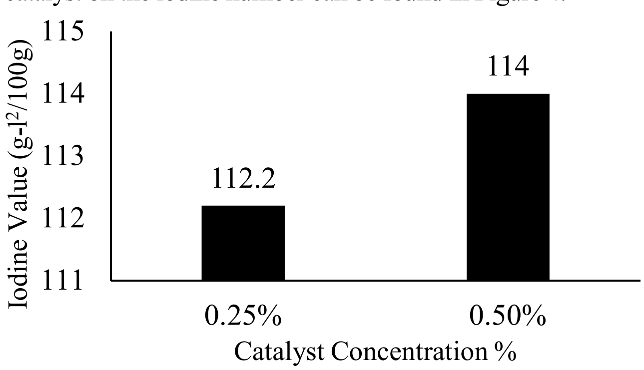

Figure 4. The influence of Catalyst on Iodine Number in Biodiesel

Figure 4 the results of testing the iodine number characteristics of biodiesel. The author observed that the higher the catalyst concentration, the higher the value of the iodine number produced, and the closer it is to the biodiesel quality standard. However, both tests were still within the biodiesel quality standard set by the Ministry of Energy and Mineral Resources, which is 115% by mass (g-l^2/100 g). Therefore, the authors conclude that the catalyst does not significantly affect the value of the biodiesel iodine number.

3 CONCLUSION

In the first experiment using 0.25% NaOH and 0.15 liters of methanol, the flash point value was 580°C. In the second experiment using 0.5% NaOH and 0.2 liters of methanol, the flash point value was 48.5°C. The lower the catalyst concentration, the higher the flash point value obtained. However, both results were still outside the biodiesel quality standards set by the Ministry of Energy and Mineral Resources. The author concluded that the results were far different from the biodiesel quality standard because the methanol solution concentration was too high. Therefore, the catalyst greatly affects the yield of the biodiesel flash point. The first experiment using 0.25% NaOH and 0.15 liters of methanol resulted in a viscosity of 4.567 x 10^6 m^2/s. The second experiment using 0.5% NaOH and 0.2 liters of methanol resulted in a viscosity of 4.625 x 10^6 m^2/s. The lower the catalyst concentration, the higher the viscosity value obtained. However, both tests were still within the biodiesel quality standards set by the Ministry of Energy and Mineral Resources. Therefore, the authors conclude that the catalyst does not affect the value of the viscosity of biodiesel. In the first experiment using 0.25% NaOH and 0.15 liters of methanol, the density was 889 kilograms per cubic meter (kg/m^3). In the second experiment using 0.5% NaOH and 0.2 liters of methanol, the density was 888.9 kg/m^3. The lower the catalyst concentration, the higher the density value obtained. However, both tests were still within the biodiesel quality standard set by the Ministry of Energy and Mineral Resources. Therefore, the authors conclude that the catalyst does not affect the value of the density of biodiesel. In the first experiment using 0.25% NaOH and 150 mL methanol, the iodine number was 112.2 g iodine per 100 grams (g/100 g) of biodiesel. In the second experiment using 0.5% NaOH and 200 mL methanol, the iodine number was 114 g/100 g of biodiesel. The higher the concentration of the catalyst, the higher the value of the iodine number produced. The iodine number values obtained from both experiments are within the biodiesel quality standard set by the Ministry of Energy and Mineral Resources (MEMR). Therefore, the authors conclude that the catalyst does not significantly affect the value of the biodiesel iodine number.

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