IPC
Indonesian Physics Communication
Department of Physics, Universitas Riau, Pekanbaru, Indonesia
p-ISSN 1412-2960 | e-ISSN 2579-521X
Vol. 22 | No. 1
March 2025
Web: https://kfi.ejournal.unri.ac.id
E-mail: kfi@ejournal.unri.ac.id

The effect of reaction time and oil-to-methanol ratio on the calorific value of biodiesel produced from chicken fat oil

Alltop Amri Ya Habib[1,*], Tengku Emrinaldi[2], Yogi Yolanda[1], Yelmida Azis[1]
[1]Department of Chemical Engineering, Universitas Riau, Pekanbaru 28293, Indonesia
[2]Department of Physics, Universitas Riau, Pekanbaru 28293, Indonesia

*Corresponding author: alltopamri@lecturer.unri.ac.id

ABSTRACT

The energy content of a fuel is represented by its calorific value. When biodiesel combusts in the presence of air or oxygen, the heat released during the combustion process is expressed as the calorific value. This study aims to analyze the effect of reaction time (60, 120, and 180 minutes) and the volume ratio of chicken fat oil-to-methanol (OM) (25:30 and 25:50) in the transesterification process on the calorific value of the produced biodiesel. The transesterification process was conducted using MgO as a catalyst under various reaction times and OM ratios. The produced biodiesel was then analyzed to determine its calorific value as a key fuel quality parameter. The results indicate that a longer reaction time and a higher OM volume ratio lead to an increase in the calorific value. The highest calorific value obtained in this study was 9952 kcal/kg, achieved at a reaction time of 180 minutes and an OM volume ratio of 25:50.

Keywords: Biodiesel; calorific value; chicken fat oil; oil-to-methanol ratio; reaction time

Received 23-02-2025 | Revised 21-03-2025 | Accepted 27-03-2025 | Published 31-03-2025

INTRODUCTION

The demand for alternative energy sources is increasing as fossil fuel reserves continue to deplete and awareness of their environmental impact grows. Biodiesel is a promising alternative fuel derived from renewable resources such as vegetable oils and animal fats. Compared to fossil fuels, biodiesel offers several advantages, including greater environmental friendliness, biodegradability, and lower greenhouse gas emissions [1-2].

One of the potential feedstocks for biodiesel production is chicken fat oil [3-4]. Chicken fat waste generated from the poultry processing industry has not been optimally utilized, despite its high triglyceride content, which makes it suitable for conversion into biodiesel through the transesterification process. This process involves a reaction between oil and methanol in the presence of a catalyst to produce methyl esters (biodiesel) and glycerol as a by product.

The efficiency and quality of the produced biodiesel are influenced by several factors, including the type of catalyst, reaction temperature, reaction time, and the oil-to-methanol (OM) ratio [5-6]. A reaction time that is too short may result in an incomplete reaction, leading to suboptimal oil-to-biodiesel (OB) conversion. Conversely, an excessively long reaction time can cause product degradation. Additionally, the oil-to-methanol ratio plays a crucial role in determining conversion efficiency. An optimal methanol ratio enhances biodiesel formation, while excess methanol can produce excessive glycerol, which may interfere with the biodiesel purification process [1, 3, 5].

Based on this background, this study was conducted to evaluate the effect of reaction time and the OM ratio on the calorific value of biodiesel produced from chicken fat oil. The calorific value is a crucial parameter for assessing fuel quality, as it determines the amount of energy generated during biodiesel combustion. By understanding the relationship between process parameters and the resulting calorific value, this research aims to contribute to the optimization of biodiesel production from chicken fat waste.

LITERATURE REVIEW

Biodiesel (Methyl Ester)

Biodiesel is an alternative fuel for diesel engines derived from renewable resources, specifically alkyl esters of fatty acids. It can be produced from vegetable oils, animal fats, or recycled waste cooking oil. As an environmentally friendly fuel, biodiesel consists of various fatty acid esters obtained from plant-based oils, such as palm oil, coconut oil, *Jatropha* oil, and kapok seed oil, as well as from animal fats, including lard, chicken fat, beef tallow, and fish oil [1].

As a substitute for conventional diesel fuel, biodiesel is produced from renewable feedstocks, including vegetable oils and animal fats. Compared to fossil fuels, biodiesel offers several advantages, such as being biodegradable, non-toxic, and having lower CO_2 and sulfur gas emissions. These characteristics make biodiesel a more environmentally sustainable fuel option. Table 1 presents the biodiesel quality standards based on SNI 7182-2015.

Table 1. Biodiesel quality standards based on SNI 7182-2015.

Parameter	Unit	Value	Test method
Density (40ºC)	kg/m^3	850 – 890	ASTM D 1298
Viscosity (40ºC)	mm^2/s (cSt)	2.3 – 6.0	ASTM D 445
Cetane number	min	51	ASTM D 613
Flash point	ºC, min	100	ASTM D 93
Fog point	ºC, max	18	ASTM D 2500
Water and sediments	%-volume, max	0.05	ASTM D 2709 / ASTM D 1796
Acid number	KOH/g, max	0.5	AOCS Cd 3d-63
Iodine number	%-massa (g-I_2/100 g), max	115	AOCS Cd 1-25
Calorific value	kcal/kg, max	9938.76	ASTM D240

The Calorific Value

The calorific value of biodiesel refers to the amount of energy released during complete combustion. Generally, biodiesel has a lower calorific value compared to fossil diesel due to its higher oxygen content. This is attributed to the chemical structure of methyl esters that make up biodiesel, where the presence of oxygen reduces the energy content per unit mass. Despite this, biodiesel remains an attractive alternative fuel as it produces cleaner emissions and excellent lubricant properties [7].

Several factors influence the calorific value of biodiesel, including fatty acid composition, feedstock type, and transesterification process parameters such as the methanol-to-oil molar ratio and reaction time. Saturated fatty acids tend to have a higher calorific value than unsaturated ones due to their more stable combustion properties. Additionally, optimizing the methanol ratio in the transesterification process is crucial to ensuring complete conversion of oil into methyl esters. If the methanol ratio is too low, the reaction may be incomplete, leading to lower energy content, whereas excessive methanol requires additional separation steps increasing production costs [8].

Besides the methanol ratio, reaction time also plays a crucial role in determining biodiesel quality and its calorific value. A reaction time that is too short can result in incomplete conversion, leaving behind higher glyceride content and reducing energy output. On the other hand, excessive reaction time may lead to the formation of unwanted by-products, such as soap or peroxides, which negatively affect combustion efficiency. Therefore, optimizing process parameters is essential in biodiesel production to achieve a calorific value comparable to conventional diesel fuels.

RESEARCH METHODS

Materials and Tools

The materials used in this study include animal oil extracted from chicken fat, MgO, methanol (CH_3OH), oxalic acid, phenolphthalein indicator, and distilled water. The equipment utilized in this research consists of beakers, a separatory funnel, a funnel, filter paper, a two-neck flask, a heating mantle, a condenser, clamps and a stand, an Erlenmeyer flask, an oven, a dropper pipette, an analytical balance, a thermometer, a pycnometer, an Ostwald viscometer, a burette, a stirring rod, a graduated cylinder, and a volumetric flask.

Procedure Reasearch

Preparation of Chicken Fat Oil

Chicken fat is first cleaned and placed in a container before being heated in an oven at 80°C for 24 hours. After the heating process, the fat is separated and filtered to obtain chicken fat oil. The extracted oil is then analyzed for its free fatty acid (FFA) content, density, moisture content, and viscosity.

Biodiesel Transesterification

A total of 25 ml of chicken fat oil is placed into a two-neck flask and heated to 60°C. Once the desired temperature is reached, 30 ml of methanol and 0.5 grams of MgO catalyst are added. The reaction is allowed to proceed for 60 minutes. After completion, the mixture is transferred to a separatory funnel and left undisturbed until two distinct layers are formed. The upper layer consists of crude biodiesel, while the lower layer contains the residual methanol and catalyst. The upper layer is separated and further purified using hot water to remove impurities. The procedure is repeated for reaction times of 120 minutes and 180 minutes, as well as for a variation in the oil-to-methanol ratio of 25:50 ml. Finally, the calorific value of the biodiesel is analyzed.

RESULTS AND DISCUSSION

The calorific value of combustion refers to the amount of heat or energy released during the burning process of a specific quantity of fuel in the presence of air or oxygen. Based on the SNI 7182-2015 standard, the maximum calorific value of biodiesel is 9938.76 kcal/kg. The calorific values obtained in this study can be observed in Figure 1, which presents the results for different reaction times (60, 120, and 180 minutes) and an OM ratio of 25:30.

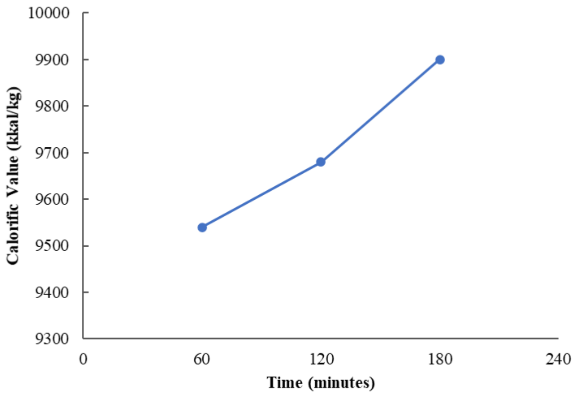

Figure 1. Calorific value at different reaction times with an OM ratio of 25:30.

Based on Figure 1, the calorific value of biodiesel increases with longer reaction times. This phenomenon occurs because extended reaction durations facilitate a more complete transesterification process, enhancing the conversion of triglycerides into methyl esters. As a result, the biodiesel produced has a lower concentration of unreacted components, such as glycerides and free fatty acids, which can negatively impact its energy content. A more complete reaction improves the purity of biodiesel, leading to a higher calorific value [9], [10]. Furthermore, optimizing reaction time minimizes the formation of undesirable by-products that could reduce combustion efficiency. However, excessively long reaction times may promote secondary reactions or biodiesel degradation, necessitating careful control to maintain fuel quality [11].

Based on Figure 2, it is evident that, in addition to reaction time, the OM ratio significantly influences the resulting calorific value. This effect can be attributed to the role of methanol in the transesterification process, where an optimal molar ratio ensures efficient conversion of triglycerides into biodiesel. Studies have demonstrated that varying the methanol-to-oil (MO) molar ratio impacts the yield and quality of biodiesel produced. For instance, research indicates that increasing the MO molar ratio can enhance biodiesel yield up to an optimal point, beyond which the yield may plateau or even decrease due to factors such as glycerol solubility in methanol and difficulties in phase separation. Therefore, selecting an appropriate OM ratio is crucial for maximizing the calorific value of biodiesel, as it ensures a more complete transesterification reaction and minimizes the presence of unreacted components that could lower the energy content of the final product [8].

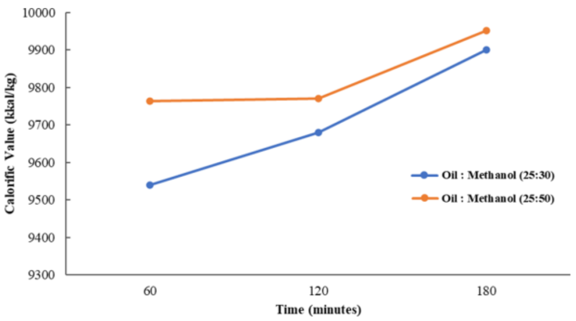

Figure 2. Calorific value at different reaction times with an OM ratio (25:30 and 25:50).

CONCLUSION

The findings indicate that both reaction time and the OM ratio play crucial roles in determining the calorific value of biodiesel. A longer reaction time enhances the transesterification process, leading to a more complete conversion of triglycerides into methyl esters, which increases the calorific. The optimal OM ratio is critical to maximize biodiesel yield and energy content, as it ensures efficient conversion while minimizing the presence of unreacted components. However, exceeding the optimal ratio may lead to a decline in biodiesel quality due to issues such as glycerol solubility and phase separation challenges. Therefore, careful optimization of these parameters is necessary to produce high-quality biodiesel with superior energy content, making it a viable and sustainable alternative to conventional diesel fuels.

REFERENCES

1. Nirmala, R. L. (2019). Pengaruh katalis CaO dari cangkang bekicot pada pembuatan biodiesel dari lemak sapi. *Jurnal Crystal*, **1**(01), 39–54.
2. Aziz, A., Mukhsin, M., & Aulia, F. (2024). Interesterifikasi biodiesel non alcohol dengan bahan baku minyak bekas. *Pros. Politeknik Negeri Lhokseumawe*, 7.
3. Habib, A. A. Y. & Suhendri, S. Pengaruh waktu reaksi transesterifikasi biodiesel dari minyak lemak ayam. *J. Bioprocess Chem. Environ. Eng. Sci.*, **5**(2), 69–76.
4. Pratama, R. V., Mardiana, M., & Niawanti, H. (2019). Pemanfaatan limbah lemak ayam broiler (*Gallus domesticus*) sebagai bahan baku. *Jurnal Chemurgy*, **2**(2), 6–14.
5. Mukminin, A., Megawati, E., & Sapril, S. (2023). Pengaruh waktu reaksi pembuatan biodiesel dari minyak jelantah dengan bantuan katalis. *J. Educ*, **5**(2), 5119–5127.
6. Muarif, A., Fatnia, F., & Bahri, S. (2024). Pengaruh suhu dan waktu reaksi terhadap hasil sintesis biodiesel dari minyak. *Jurnal Teknologi Kimia Unimal*, **13**(1), 58–71.
7. Putra, R., Supriyadi, S., & Suheli, S. (2021). Analisa pembuatan biodiesel minyak jelantah dengan katalis. *J. Vocat. Educ. Automot. Technol.*, **3**(1), 137–145.
8. Prihanto, A. & Irawan, T. B. (2018). Pengaruh temperatur, konsentrasi katalis dan rasio molar metanol-minyak terhadap yield biodisel. *Metana*, **13**(1), 30–36.
9. Foroutan, R., Mohammadi, R., & Ramavandi, B. (2021). Waste glass catalyst for biodiesel production from waste chicken fat. *Fuel*, **291**, 120151.
10. Kirubakaran, M. & Selvan, V. A. M. (2018). A comprehensive review of low cost biodiesel production. *Renew. Sustain. Energy Rev.*, **82**, 390–401.
11. Banga, S. & Pathak, V. V. (2023). Biodiesel production from waste cooking oil. *Energy Nexus*, **10**, 100209.