



## Study on the Effect of Simple Used Cooking Oil Filtration Composition on Biodiesel Quality for Generator Fuel

Afrizal Abdi Musyafiq<sup>1</sup>, Novita Asma Ilahi<sup>2</sup>, Oki Saputra<sup>3</sup>

<sup>1</sup>Department of Electrical Engineering, Politeknik Negeri Cilacap, Indonesia, 53212

<sup>2</sup>Department of Electronics Engineering, Politeknik Negeri Cilacap, Indonesia, 53212

<sup>3</sup>Department of Agricultural Engineering, Universitas Mataram, Indonesia, 83115

[nasmalahi@pnc.ac.id](mailto:nasmalahi@pnc.ac.id)

<https://doi.org/10.37339/e-komtek.v9i2.2908>

Published by Politeknik Piksi Ganesha Indonesia

### Abstract

#### Artikel Info

Submitted:

10-12-2025

Revised:

15-12-2025

Accepted:

18-12-2025

Online first :

31-12-2025p

Used cooking oil has great potential as a raw material for biodiesel because it is abundant and inexpensive, but its quality often deteriorates due to high free fatty acid and impurity levels. This study examines the effect of variations in simple filtration composition on improving the quality of used cooking oil before it is converted into biodiesel. Filtration uses a combination of activated charcoal, fine sand, and zeolite in specific ratios. The parameters tested included density at 15°C, kinematic viscosity at 50°C, and the calorific value of the biodiesel produced. The results showed that the optimal filtration composition produced B40 biodiesel at a temperature of 50–60°C with a density of 868.5 kg/m<sup>3</sup>, kinematic viscosity of 3.570 mm<sup>2</sup>/s, and calorific value of 9772.4 kcal/g, which meets the SNI 7182:2015 standard. In addition, biodiesel from simply filtered used cooking oil has been proven to be usable as generator fuel with an energy efficiency of 34.79% in an 8.5 kVA generator test. These findings offer a simple, inexpensive, and environmentally friendly alternative for processing used cooking oil to support the availability of renewable energy.

**Keywords:** *used cooking oil; simple filtration composition; biodiesel; generator fuel; raw material quality*

### Abstrak

Minyak jelantah berpotensi besar sebagai bahan baku biodiesel karena ketersediaannya melimpah dan harganya murah, namun kualitasnya sering menurun akibat tingginya asam lemak bebas dan pengotor. Penelitian ini mengkaji pengaruh variasi komposisi filtrasi sederhana terhadap peningkatan kualitas minyak jelantah sebelum dikonversi menjadi biodiesel. Filtrasi menggunakan kombinasi arang aktif, pasir halus, dan zeolit dengan rasio tertentu. Parameter yang diuji mencakup densitas pada 15°C, viskositas kinematik pada 50°C, dan nilai kalor biodiesel yang dihasilkan. Hasil penelitian menunjukkan bahwa komposisi filtrasi optimal menghasilkan biodiesel B40 pada suhu 50–60°C dengan densitas 868,5 kg/m<sup>3</sup>, viskositas kinematik 3,570 mm<sup>2</sup>/s, dan nilai kalor 9772,4 kkal/g, yang memenuhi standar SNI 7182:2015. Selain itu, biodiesel dari minyak jelantah yang difiltrasi sederhana ini terbukti dapat digunakan sebagai bahan bakar generator dengan efisiensi energi 34,79% dalam pengujian generator 8,5 kVA. Temuan ini menawarkan alternatif pengolahan minyak jelantah yang sederhana, murah, dan ramah lingkungan untuk mendukung ketersediaan energi terbarukan.

**Kata-kata kunci:** *minyak jelantah; komposisi filtrasi sederhana; biodiesel; bahan bakar genset; kualitas bahan baku*



This work is licensed under a [Creative Commons Attribution-NonCommercial 4.0 International License](https://creativecommons.org/licenses/by-nc/4.0/).

## 1. Introduction

Fossil-based energy is still the main source for meeting energy demands across various sectors, including transportation and small-scale power generation such as generators [1][2]. The high dependency on fossil fuels causes several problems, including limited resources, fluctuations in global oil prices, and environmental impacts in the form of greenhouse gas emissions. On the other hand, electricity demand in rural or remote areas often still relies on diesel generators due to limited access to the national electricity grid (PLN) [3][4]. This necessitates the search for alternative energy sources that are more environmentally friendly, renewable, and economical. One promising raw material is used cooking oil, which is abundant but underutilized [5][6][7]. Used cooking oil is typically discarded, leading to environmental pollution in water and soil. Therefore, using used cooking oil as a raw material for biodiesel can be a dual solution: reducing environmental pollution while providing an alternative energy source for generators [8][9].

Previous studies have used used cooking oil to produce biodiesel via transesterification using acid or base catalysts. The results show that biodiesel from used cooking oil has combustion characteristics similar to diesel and can be used in diesel engines with little or no modification [10][11]. Research also shows that biodiesel from used cooking oil can reduce carbon monoxide and particulate emissions compared to pure diesel [12][13]. Furthermore, it can be processed at low cost due to its abundant availability and non-competition with food supply, unlike pure vegetable oils. Thus, the potential of using used cooking oil for biodiesel has been globally recognized and has been the focus of renewable energy research over the past two decades [14].

A major issue in utilizing used cooking oil for biodiesel is its low initial quality. It usually contains high water content, free fatty acids (FFA), and dissolved impurities due to repeated frying processes [15][16]. These parameters significantly affect the efficiency of the transesterification process and the quality of the resulting biodiesel. Several studies have tried improving used oil quality through pre-treatment such as chemical neutralization, heating, or using special adsorbents like activated carbon or zeolite. However, the complexity and high cost of such methods often hinder their application at a small or community scale [17][18].

Most studies on purifying used cooking oil rely on complex and expensive equipment, which may not be suitable for household or small-scale community applications [19][20]. Only a few studies have specifically explored the use of simple filtration methods with varying media compositions to improve the quality of used cooking oil before biodiesel production. Moreover, there is limited research linking the variation of simple filtration to biodiesel quality and its performance as generator fuel. This approach has the potential to offer a practical, low-cost, and eco-friendly solution for rural communities needing alternative energy sources [21][22].

This research introduces a simple purification method using easy-to-find materials such as activated carbon, fine sand, and zeolite. Unlike previous studies that used complex technologies, this method emphasizes simplicity, low cost, and easy replication at the community level. The variation in filtration media composition is expected to reduce FFA, moisture content, and viscosity, thereby improving the quality of biodiesel feedstock. Therefore, this study aims to bridge the gap between the need for practical technology and the production of high-quality biodiesel for generator fuel [23].

The novelty of this research lies in three key aspects: the variation in simple filtration media composition, the direct relationship between biodiesel quality and generator fuel performance, and a small-scale approach that can be applied in the community. This study not only considers the chemical parameters such as FFA and viscosity but also practically tests how the biodiesel affects generator performance. Thus, the research is expected to contribute both scientifically and practically to the development of renewable energy based on household waste [24].

This study becomes even more relevant with the increasing consumption of cooking oil in the community and the rising amount of improperly managed used oil. If left unchecked, the disposal of used cooking oil can pollute water bodies, clog drainage, and degrade soil quality. On the other hand, the electricity demand in remote areas not yet served by PLN remains high, while fuel prices continue to rise. Converting used cooking oil into quality biodiesel using simple methods offers two simultaneous benefits: providing alternative energy and reducing waste [25][26].

Based on this background, this study aims to analyze the effect of variations in simple filtration media composition on the quality of used cooking oil as biodiesel feedstock and its performance as generator fuel. The research methods include filtration using various media compositions, biodiesel production through transesterification, and biodiesel quality testing based on SNI standards. The produced biodiesel is also tested on generators to evaluate combustion performance. The study results are expected to offer practical recommendations on optimal filtration composition to produce quality biodiesel using simple and low cost technology.

## **2. Method**

### **2.1. Tools and Materials**

The main material used in this research is used cooking oil obtained from household and local food business waste. The filtration media include activated carbon, fine sand, and zeolite, each with uniform grain sizes. Other chemicals used in the transesterification process include technical methanol (CH<sub>3</sub>OH) and sodium hydroxide (NaOH) with 99.99% purity. The main equipment consists of a stainless-steel transesterification reactor, a heater and stirrer, filtration

funnel, viscometer, digital density meter, and bomb calorimeter for calorific value testing [27][28].

## 2.2. Filtration Composition Variations

The filtration process was conducted using three types of filtering media combined in different compositions. Each combination consists of a mixture of activated carbon (A), silica fine sand (P), and zeolite (Z) in varying mass ratios. The tested compositions are shown in Table 1. The goal is to determine the optimal composition that produces the best-quality used cooking oil for biodiesel feedstock.

**Table 1.** Filtration Media Composition Variations

Sample Code	Activated Carbon (%)	Fine Sand (%)	Zeolite (%)
F1	40	30	30
F2	50	25	25

## 2.3. Research Procedure

The research procedure was designed to ensure that every stage of the filtration, biodiesel production, and fuel testing process can be replicated accurately. The main steps include raw material preparation, used oil filtration, transesterification, phase separation, and biodiesel quality testing according to SNI standards. Each step maintains consistent process variables to allow objective comparisons between filtration variations [29][30].

The first stage is the preparation of used cooking oil, which involves initial filtering using a cloth filter to remove large particles and coarse impurities. The oil is then heated to approximately 100°C for 10–15 minutes to reduce its moisture content. Moisture reduction is crucial to prevent negative effects on the transesterification reaction. After heating, the oil is allowed to cool to a safe temperature before proceeding to the filtration stage [31].

The second stage is the main filtration using a combination of activated carbon, fine sand, and zeolite media based on the variations listed in Table 1. Each medium is layered within a filtration column in a specific order to ensure optimal adsorption and filtering capabilities. The used cooking oil is slowly poured into the filtration column, and the filtered result is collected in a glass container to maintain purity. This process is repeated twice to ensure consistency in oil clarity for each filtration composition [32].

The third stage is the transesterification process, in which the filtered oil is mixed with methanol and NaOH as a catalyst. The mixture is heated to 60°C and stirred for 60 minutes using

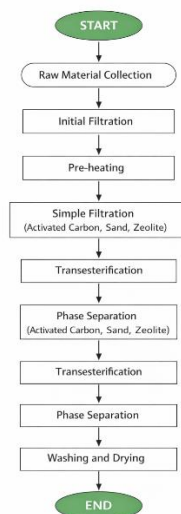
a hot plate stirrer. The molar ratio of oil to methanol is maintained at the common ratio of 1:6 to ensure effective conversion of triglycerides into methyl esters. After the reaction is complete, the mixture is left to settle for 12 hours to allow gravity-based separation of glycerol from biodiesel [33].

The fourth stage is the washing and drying of biodiesel. The biodiesel separated from glycerol is washed with warm water in several stages until the pH approaches neutral. The washing process is carried out using the mist-washing method to prevent emulsification. After that, the biodiesel is dried at a low temperature to remove residual water. The clean and dry biodiesel is then further tested.

The final stage is biodiesel quality testing, which includes measuring the density at 15°C, kinematic viscosity at 50°C, and calorific value using a bomb calorimeter. These tests are conducted to compare the performance of each filtration variation and assess their compliance with SNI 7182:2015 standards. Additionally, the best-performing biodiesel is tested as generator fuel to evaluate its energy efficiency and combustion performance under specific loads. All procedures are conducted following laboratory safety protocols [34][35].

#### 2.4. Research Flow Diagram

The research flow diagram is designed to provide a systematic overview of the entire sequence of processes, from raw material collection to biodiesel quality testing. The flowchart helps to structure the research process and makes it easier for readers to understand the sequence and interrelation of each stage. Every step in the diagram represents a crucial process that influences the final quality of the biodiesel, and its construction considers logical, technical, and standard methodological aspects.



**Gambar 1.** Flowchart Penelitian Filtrasi Biodiesel

The initial stage in the flowchart begins with the collection of used cooking oil obtained from household and culinary business waste. The collected oil undergoes an initial screening to remove coarse particles. This is followed by a pre-heating process to reduce moisture content that could interfere with chemical reactions in the transesterification stage. This step is a critical foundation to ensure that the oil meets the criteria for biodiesel feedstock.

The next stage is the filtration using simple media composed of activated carbon, fine sand, and zeolite in specific compositions. This filtration process aims to eliminate dissolved impurities, increase oil clarity, and reduce FFA levels and microscopic contaminants. The filtered oil is then used as the feedstock for the next process: transesterification, which converts triglycerides into methyl esters with the aid of methanol and NaOH as a catalyst. This stage is followed by glycerol separation to obtain crude biodiesel.

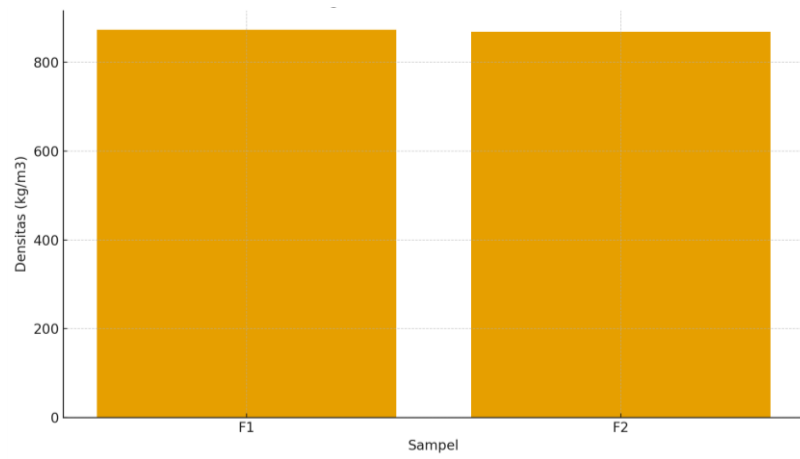
Next, the crude biodiesel undergoes washing and drying to remove residual catalysts, soap, and methanol still present in the biodiesel. Washing is repeated until the pH approaches neutral, then the biodiesel is dried to remove residual water vapor. The cleaned biodiesel then proceeds to the quality testing stage.

The final stage in the flow diagram involves the characterization of biodiesel, including measurements of density, kinematic viscosity, and calorific value. In addition to laboratory tests, the best filtered biodiesel is also tested in an 8.5 kVA generator to assess energy efficiency and combustion performance. The data from these tests are used as a basis for the results analysis and discussion in the following chapters.

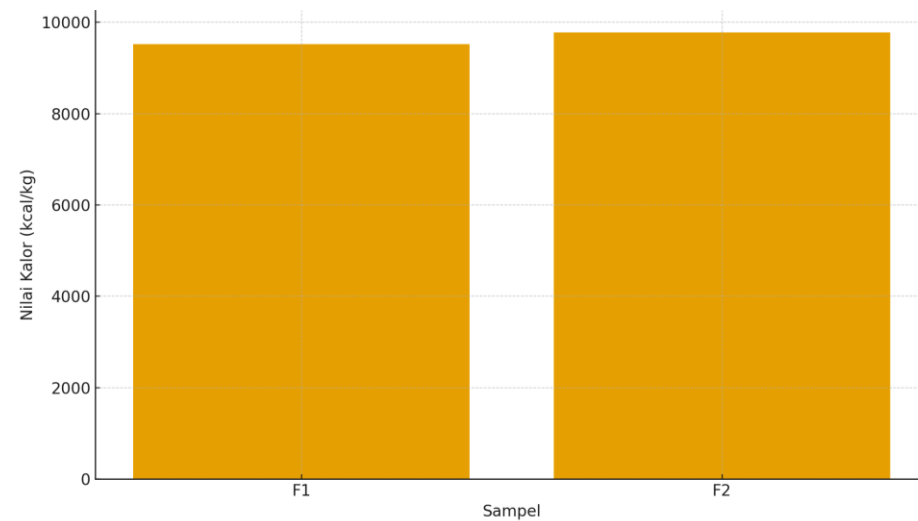
Overall, this research flowchart provides a comprehensive visualization of the interrelation between processes, aiding replication and ensuring methodological consistency. The flowchart can be presented in a process diagram format that shows each stage sequentially from input (raw materials) to output (tested biodiesel). This diagram serves as a crucial reference in documenting experimental stages in academic research.

### 3. Results and Discussion

The comparison charts showing density, viscosity, and calorific value of biodiesel samples F1 and F2 reveal consistent quality differences between the two. The data indicate that while both samples fall within the SNI standard range, F2 consistently demonstrates better performance. This is evident from F1's slightly higher density, suggesting the presence of more contaminants. F1's viscosity is also higher, indicating that the filtration was less effective in removing heavy molecules. Additionally, F1's lower calorific value implies that the combustion energy is still affected by water content and non-energetic compounds. These visual representations confirm that simple filtration plays a crucial role in enhancing the quality of used cooking oil. The right filtration media composition directly impacts the efficiency of the transesterification process. Overall, the graphs reinforce the success of using F2 as the optimal composition in this study.



**Figure 2.** Comparison of Biodiesel Density between Samples F1 and F2



**Figure 3.** Comparison of Biodiesel Kinematic Viscosity of Samples F1 and F2 at 50°C

#### 4. Conclusion

This study has proven that a simple filtration process using a combination of activated carbon, fine sand, and zeolite can significantly improve biodiesel quality. The variation in filtration media compositions showed that sample F2 produced the best physical characteristics, with a density of 868.5 kg/m<sup>3</sup>, a viscosity of 3.57 mm<sup>2</sup>/s, and a calorific value of 9772.4 kcal/kg, all of which fall within the SNI 7182:2015 standard limits. The effectiveness of this filtration lies in its ability to reduce FFA content, moisture, and heavy molecules, thereby enhancing the efficiency of the transesterification reaction. The difference between F1 and F2 confirms that biodiesel quality strongly depends on the effectiveness of initial purification before the chemical process. These findings fulfill the first research objective: to determine the impact of filtration media composition variation on improving the quality of used cooking oil as biodiesel feedstock. In general, simple filtration proves to be a low-cost, easy-to-apply method that can be replicated at household or community scale. Its success opens up opportunities to utilize used cooking oil as an alternative energy source. Thus, this research provides a significant contribution to the development of renewable energy based on household waste.

This study also demonstrates that biodiesel produced through simple filtration has considerable energy potential to be used as fuel for generator-based electricity production. Energy conversion analysis shows that F2 biodiesel contains 11.36 kWh per kilogram, equivalent to 9.86 kWh per liter, while F1 yields 11.07 kWh/kg or 9.66 kWh per liter. When associated with the 8.5 kVA generator efficiency of 34.79%, F2 biodiesel can generate approximately 3.43 kWh of electricity per liter, while F1 produces around 3.36 kWh per liter. These values confirm that biodiesel from used cooking oil not only meets fuel quality standards but also has real potential as a small-scale electricity source. Generator tests showed that F2 biodiesel maintains stable engine rotation and combustion without additional modifications. These findings meet the second research objective: to assess the feasibility of biodiesel as generator fuel. Overall, this study proves that biodiesel from used cooking oil can be a clean, economical, and sustainable energy solution, especially for electricity needs in areas not yet connected to the national grid.

## 5. Acknowledgement

The authors would like to express their gratitude to the Directorate of Research and Community Service, Directorate General of Research and Development, Ministry of Higher Education, Science, and Technology for funding support through the Beginner Lecturer Research scheme for Fiscal Year 2025. The authors also extend their appreciation to the State Polytechnic of Cilacap, particularly the Center for Research and Community Service (P3M), for providing facilities, guidance, and administrative support throughout the implementation of this research. Special thanks are also given to the entire research team and students from the Electrical Engineering Study Program who contributed to the data collection, biodiesel testing, and generator experiments that enabled this research to be successfully completed.

## References

- [1] H. Hadrah, M. Kasman, and F. M. Sari, "Analisis minyak jelantah sebagai bahan bakar biodiesel dengan proses transesterifikasi," *Jurnal Daur Lingkungan*, vol. 1, no. 1, pp. 16–21, 2018.
- [2] J. Prasetyo, "Studi pemanfaatan minyak jelantah sebagai bahan baku pembuatan biodiesel," *Jurnal Ilmiah Teknik Kimia UNPAM*, vol. 2, no. 2, pp. 1–10, 2018.
- [3] C. W. A. Dewi, "Analisis pembuatan biodiesel dari minyak jelantah," *Agroteknose: Jurnal Teknologi dan Enjiniring Pertanian*, vol. 7, no. 2, 2018.
- [4] J. Harahap and Y. Yullia, "Potensi pemanfaatan limbah minyak jelantah Kota Banda Aceh sebagai sumber energi alternatif (biodiesel)," *Elkawanie: Journal of Islamic Science and Technology*, vol. 4, no. 2, pp. 151–164, 2018.
- [5] A. Kapuji, S. Hadi, and Z. Arifin, "Proses pembuatan biodiesel dari minyak jelantah," *Jurnal Chemtech*, vol. 7, no. 1, pp. 1–6, 2021.
- [6] D. A. Setyawardhani, A. T. Y. Widiastri, and M. Rahman, "Uji karakteristik pencampuran biodiesel minyak jelantah dan biodiesel minyak kesambi," *Jurnal Integrasi Proses*, vol. 10, no. 2, pp. 68–76, 2021.
- [7] S. Oko, A. Kurniawan, and J. Rahmatina, "Pengaruh perbandingan massa Ca dan C pada katalis NaOH/CaO/C dalam sintesis biodiesel menggunakan minyak jelantah," in *Prosiding Industrial Research Workshop and National Seminar*, vol. 12, pp. 423–428, Sep. 2021.
- [8] P. Wahyuningsih, "Bentonit tersulfatasi sebagai katalis dalam produksi biodiesel dari minyak jelantah," *QUIMICA: Jurnal Kimia Sains dan Terapan*, vol. 4, no. 1, pp. 5–8, 2022.
- [9] R. Putra, S. Supriyadi, and S. Suheli, "Analisa pembuatan biodiesel minyak jelantah dengan katalis basa," *Journal of Vocational Education and Automotive Technology*, vol. 3, no. 1, pp. 137–145, 2021.

- [10] H. N. Aulia and A. Mokhtar, "Pengaruh tegangan listrik dan rasio solven pada sintesis biodiesel dari minyak jelantah metode elektrokatalitik," in *Seminar Keinsinyuran Program Studi Program Profesi Insinyur*, vol. 2, no. 1, 2022.
- [11] Y. C. Sari, R. Junaidi, and A. Hasan, "Penggunaan batu kapur sebagai katalis heterogen untuk pembuatan biodiesel dari minyak jelantah," *Jurnal Pendidikan dan Teknologi Indonesia*, vol. 2, no. 8, pp. 363–371, 2022.
- [12] B. A. Saputro and A. Abdurrahman, "Karakteristik biodiesel dari campuran bahan bakar dextrite dan minyak jelantah tanpa perlakuan pada mesin diesel," *Jurnal Teknik Kimia*, vol. 28, no. 2, pp. 51–59, 2022.
- [13] H. A. Azis et al., "Penggunaan adsorben bentonit pada proses pencucian kering dalam pemurnian biodiesel minyak jelantah," *Jurnal Teknik Kimia USU*, vol. 12, no. 2, pp. 108–115, 2023.
- [14] C. F. Sutanto, F. P. Wiryawan, and F. Kurniawansyah, "Pra Rancangan Pabrik Biodiesel dari Minyak Jelantah Menggunakan Metode Transesterifikasi dengan Kapasitas 50.000 Ton/Tahun," *Jurnal Teknik ITS*, vol. 10, no. 2, pp. F210–F215, 2021.
- [15] T. Susanti and S. Santosa, "Studi penggunaan katalis CaO–NaOH pada produksi biodiesel dari minyak jelantah," *DISTILAT: Jurnal Teknologi Separasi*, vol. 8, no. 2, pp. 294–300, 2022.
- [16] A. Mukminin et al., "Pengaruh waktu reaksi pembuatan biodiesel dari minyak jelantah dengan bantuan katalis basa NaOH terhadap sifat fisika dan kimia produk biodiesel," *Journal on Education*, vol. 5, no. 2, pp. 3817–3825, 2023.
- [17] H. Hasanudin et al., "Hydrocracking optimization of palm oil to bio-gasoline and bio-aviation fuels using molybdenum nitride-bentonite catalyst," *RSC Advances*, vol. 12, no. 26, pp. 16431–16443, 2022.
- [18] M. Utami et al., "Photocatalytic degradation of naphthol blue from batik wastewater using functionalized TiO<sub>2</sub>-based composites," *Chemosphere*, vol. 337, 139224, 2023.
- [19] S. J. Sekewael et al., "Recent progress on sulfated nanozirconia as a solid acid catalyst in the hydrocracking reaction," *Catalysts*, vol. 12, no. 2, 191, 2022.
- [20] S. Gea et al., "A comprehensive review of experimental parameters in bio-oil upgrading from pyrolysis of biomass to biofuel through catalytic hydrodeoxygenation," *BioEnergy Research*, vol. 16, no. 1, pp. 325–347, 2023.
- [21] S. Azis, M. Mustam, N. Ramdani, I. I. Amin, N. Sari, and G. Gregorius, "Penggunaan adsorben bentonit pada proses pencucian kering dalam pemurnian biodiesel minyak jelantah," *Jurnal Teknik Kimia USU*, vol. 12, no. 2, pp. 108–115, 2023.
- [22] Haryono, "Preparasi minyak goreng bekas sebagai bahan baku pembuatan biodiesel dengan adsorben arang aktif dari tempurung kelapa," dalam *Prosiding Seminar Nasional ReTII*, 2025.
- [23] R. Maghfirah and A. K. Amin, "Purifikasi biodiesel berbasis minyak jelantah secara ...," *Jurnal Teknologi Rekayasa (Politeknik Negeri Lhokseumawe)*, vol. 9, no. 1, 2025. (mengulas pemurnian biodiesel MJ dengan teknik filtrasi/adsorpsi).
- [24] J. C. Hananto and N. Rosdiana, "Penurunan asam lemak bebas minyak jelantah menggunakan karbon aktif ampas tebu," *Jurnal Energi dan Sumberdaya Terbarukan*, vol. 3, no. 2, 2023 – fokus pada pretreatment adsorptif minyak jelantah sebelum proses biodiesel.
- [25] W. N. A. W. Osman, M. H. Rosli, W. N. A. Mazli, and S. Samsuri, "Comparative review of biodiesel production and purification," *Carbon Capture Science & Technology*, vol. 13, p. 100264, 2024, doi: 10.1016/j.ccst.2024.100264.

- [26] G. L. Camilo, M. R. da Silva, J. L. Ferrari, and L. F. F. Lacerda, "Review of biodiesel production using various feedstocks and its purification through several methodologies, with a specific emphasis on dry washing," *Journal of Industrial and Engineering Chemistry*, vol. 136, pp. 1–15, 2024, doi: 10.1016/j.jiec.2024.02.016.
- [27] O. Awogbemi and D. A. Desai, "Recent advances in purification technologies for biodiesel-derived crude glycerol," *International Journal of Ambient Energy*, vol. 46, no. 1, pp. 1–15, 2025, doi: 10.1080/01430750.2025.2533373.
- [28] M. C. S. Gomes, D. R. da Silva, J. A. A. dos Santos, and V. R. de Sousa, "Purification of crude glycerol derived from biodiesel production using ceramic membranes: Experimental studies and modeling," *Separation and Purification Technology*, vol. 338, p. 126055, 2025, doi: 10.1016/j.seppur.2024.126055.
- [29] T. Attarbach, M. Ghasemi, and H. Bazyari, "Waste-derived low-grade glycerol purification and recovery for sustainable applications: A mini review," *Biofuels, Bioproducts and Biorefining*, 2024, doi: 10.1002/bbb.2638.
- [30] C. G. Lopresto, M. G. De Paola, and V. Calabrò, "De-acidification of waste cooking oils by adsorption on desulfurization sorbents for high-quality biodiesel production," *Chemosphere*, vol. 380, p. 144460, 2025, doi: 10.1016/j.chemosphere.2023.144460.
- [31] R. Bostan, D. Cojocar, and M. Mardare, "Utilization of natural adsorbents in the purification of used sunflower and palm cooking oils," *Applied Sciences*, vol. 14, no. 11, p. 4417, 2024, doi: 10.3390/app14114417.
- [32] C. G. Smolich, S. M. Dias, and A. L. M. Porto, "Purification of biodiesel using a natural-based adsorbent in a packed-bed column," in *Proc. XXVII Encontro Luso-Galego de Química*, Porto, Portugal, 2023.
- [33] M. D. Guimarães, F. Rodrigues, S. M. Dias, and A. Porto, "Production of biodiesel from waste cooking oils and purification using adsorption techniques with natural adsorbents," in *Proc. XXVII Encontro Luso-Galego de Química*, Porto, Portugal, 2023.
- [34] C. F. Sutanto, F. P. Wiryawan, and F. Kurniawansyah, "Cork waste-based adsorbents for glycerol removal from biodiesel," *Biofuels*, 2025, doi: 10.1080/17597269.2025.2517453.
- [35] A. A. N. M. Al-Haimi, M. Al-Shahri, A. M. Al-Harrasi, and O. Basheer, "Optimization of crude glycerol purification from grease trap waste biodiesel production using synergistic mixed extraction alcohols," *Journal of Chemical Technology and Biotechnology*, 2024, doi: 10.1002/jctb.7688.
- [36] N. F. N. M. Redzuan, A. R. M. Shafie, N. H. Mat Yusoff, and R. Omar, "Green valorization of coconut-oil-derived crude glycerol via optimized solvent-aided solidification," *Next Research*, vol. 2, no. 4, p. 101022, 2025, doi: 10.1016/j.nexres.2025.101022.
- [37] E. Emmanouilidou, A. Koutsoukos, and P. Tsiakaras, "Green upgrading of biodiesel derived from biomass wastes," *Proceedings*, vol. 87, no. 1, p. 14, 2025, doi: 10.3390/proceedings8701014.
- [38] M. H. Pranta, S. Hossain, R. Saha, and M. R. Islam, "A comprehensive review of the evolution of biodiesel as a sustainable fuel," *Energy*, 2025, doi: 10.1016/j.energy.2025.130124.
- [39] M. Yaghi, O. S. Ahmed, and L. O. Nawar, "An overview of biodiesel production via heterogeneous catalysts," *Energies*, vol. 18, no. 3, pp. 1–30, 2025.
- [40] N. Mhetras, S. Kulkarni, and G. Nadgauda, "Sustainable biodiesel production: Importance of feedstock and process parameters," *Biofuels*, 2025, doi: 10.1080/17597269.2025.2517401.