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Synthesis of Catalyst from Agricultural Wastes for Palm Oil Conversion into Biodiesel

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Abstract

The increasing demand for sustainable energy has encouraged the search for cost-effective and environmentally friendly catalysts for biodiesel production. Homogeneous catalysts are commonly used in transesterification, but their corrosive nature and difficulty in separation reduce their practicality. This study investigates the use of banana, durian, and mango peels as heterogeneous catalysts derived from agricultural waste. These peels were dried and calcined at temperatures ranging from 400 °C to 600 °C to produce ash catalysts, which were then tested for biodiesel production from palm oil. SEM-EDX analyses revealed that banana peel ash had the highest potassium content at 52.24 wt.%, followed by durian and mango peels. FTIR analysis of the biodiesel confirmed strong ester peaks at 1740 cm^{-1}, indicating successful methyl ester formation. Among the three catalysts, banana peel ash demonstrated the most effective catalytic activity, yielding biodiesel with a yield above 90%. This study demonstrates the potential of fruit peel waste as a sustainable source of a catalyst for biodiesel production.

1. Introduction

The growing depletion of fossil fuels and the need to reduce greenhouse gas emissions have intensified global interest in alternative fuels [1]. Biodiesel, produced from renewable biological sources such as vegetable oils and animal fats, has gained attention as a cleaner-burning alternative to petroleum diesel [2]. It offers several advantages, including biodegradability, non-toxicity, and compatibility with existing diesel engines [3].

Biodiesel is typically synthesised through a chemical reaction known as transesterification, where triglycerides react with alcohol (usually methanol) in the presence of a catalyst [4]. The selection of an appropriate catalyst has a significant influence on the yield, cost, and environmental impact of the process [5]. Homogeneous catalysts such as sodium hydroxide (NaOH) and potassium hydroxide (KOH) are commonly used due to their high reaction rates. However, their drawbacks include difficulty in separating from the product, high water sensitivity, and the production of soap as a byproduct, which reduces the purity of biodiesel [6].

To overcome these limitations, heterogeneous catalysts are being explored. These catalysts are easier to separate, reusable, and environmentally benign. Recently, agricultural waste has emerged as a promising source for low-cost heterogeneous catalysts. Fruit peels, in particular, contain significant amounts of potassium, calcium, and magnesium, which are beneficial in catalysing the transesterification reaction [7].

In Malaysia, fruit consumption is high, and waste from banana, durian, and mango peels is abundant. These wastes are typically discarded and contribute to landfill issues. Converting them into value-added products such as biodiesel catalysts offers both economic and environmental benefits. Although several studies have examined individual waste types, comparative studies on different fruit peel ashes as catalysts remain limited [8].

This study aims to synthesise heterogeneous catalysts from banana, durian, and mango peels through calcination. The catalysts are characterised by Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray (EDX) analysis. Their performance in biodiesel production is evaluated using palm oil as feedstock, and the final biodiesel is analysed through Fourier Transform Infrared (FTIR) spectroscopy to confirm ester formation. The study aims to determine which type of peel offers the best catalytic performance, thereby contributing to the development of sustainable biodiesel.

2. 2. Method and Materials

Banana, durian, and mango peels were collected from local markets and households in the vicinity of Pagoh, Johor. Methanol (analytical grade) and refined palm oil were purchased from a commercial supplier. All materials were used without further purification.

2.1 2.1 Catalyst Preparation

The collected peels were thoroughly washed with tap water to remove dirt and organic residues. They were then sliced into smaller pieces and sun-dried for 24 hours to reduce moisture content. Once dried, the samples were subjected to calcination in a muffle furnace. The selected temperatures are 400 °C, 500 °C, and 600 °C for each of the banana peel, durian peel, and mango peel [9]. The three different temperatures were selected because they correspond to average temperatures suitable for the peel to become an ash catalyst, as stated in an article and journal by another researcher [9]. After calcination, it acted as a heterogeneous catalyst, with high concentrations of potassium oxide (K_2O) and potassium carbonate (K_2CO_3). These compounds facilitate the transesterification reaction between triglycerides and methanol, which is a key step in biodiesel production [10], [11].

2.2 2.3 Synthesis of Biodiesel

The transesterification process was conducted by reacting palm oil with methanol in the presence of the prepared catalysts. The ratio used was 120 g methanol to 20 g oil with 2 wt.% catalyst. The mixture was heated at 65 °C and stirred for 90 minutes. The resulting mixture was filtered using filter paper to separate the used catalyst from the produced biodiesel and glycerol. Next, the two layers of biodiesel and glycerol were separated using a separation funnel [12].

3. 3. Results and Discussion

4. The characterisation of both catalyst and biodiesel was discussed as in the following sub-topics.

4.1 Catalyst Characterisation

4.2 3.1.1 Scanning Electron Microscopy (SEM)

5. The surface morphology of the catalyst was observed using SEM, and elemental composition was analysed via EDX. The focus was on potassium and magnesium content, which are known to promote transesterification. The biodiesel samples were analysed using FTIR spectroscopy (4000 – 500 cm^{-1}) to confirm the formation of fatty acid methyl esters (FAME) through identification of functional groups such as C=O, C–O, and C–H bonds [13].

6. The analysis results on the durian peel ash catalyst showed a high presence of potassium and magnesium, while the mango peel ash catalyst showed the presence of potassium, magnesium, phosphorus and silica. Similarly, the analysis results on the banana peel ash catalyst showed the presence of potassium and magnesium. The high content of potassium and magnesium in these three types of fruit peel ash catalysts makes them useful as a catalyst in the transesterification process for biodiesel production [14], [15].

7. Fig. 1 shows the SEM images of durian peel catalyst at a size of 25 nanometres. The SEM image of the durian peel catalyst affirmed that this catalyst has a highly porous structure, especially at the intersection. This high porosity results in a high surface area, providing more active sites for chemical reactions.

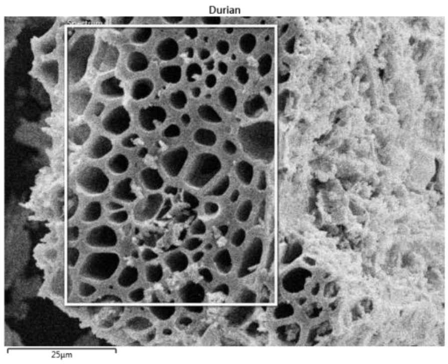

Fig. 1 *SEM image of durian peel ash catalyst*

Table 1 *Chemical composition of durian peel ash catalyst*

Element	Line Type	Weight %	Weight % Sigma	Atomic %
K	K series	30.72	4.06	15.91
Mg	K series	8.36	2.43	6.97
O	K series	60.92	5.00	77.12
Total		100.00		100.00

Table 1 shows the composition of the durian peel ash. Based on the EDX pattern, the content of Magnesium (Mg) and Potassium (K) are 8.36 wt.% and 30.72 wt.% respectively, which are considered high. This strongly supports that durian peel ash has the potential for basic catalytic behaviour because both Potassium and Magnesium are often found in basic catalysts[16]. Lastly, the high oxygen content, at 60.92 wt.%, indicates the presence of oxides that are common in heterogeneous catalysts [9], [16].

Fig. 2 shows the SEM images of the mango peel catalyst at a size of 25 nanometres. The SEM image of the mango peel catalyst shows an amorphous porous structure, but not as detailed as the durian peel catalyst SEM image. Nonetheless, this also proved that the mango peel catalyst has a high surface area, which is crucial for a basic catalyst.

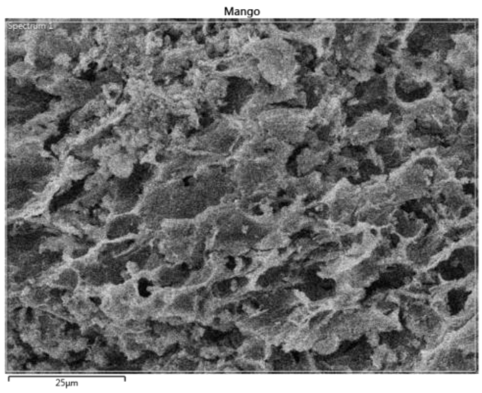

Fig. 2 *SEM image of mango peel ash catalyst*

Table 2 *Chemical composition of mango peel ash catalyst*

Element	Line Type	Weight %	Weight % Sigma	Atomic %
K	K series	27.39	2.85	14.02
P	K series	1.31	1.23	0.85
Mg	K series	3.56	1.41	2.93
Si	K series	4.69	1.20	3.34
O	K series	63.04	3.63	78.86
Total		100.00		100.00

Table 2 shows the composition of the mango peel catalyst. Based on the EDX pattern, the content of potassium (K) and magnesium (Mg) is 27.39 wt.% and 1.41 wt.%, respectively, which contains the lowest potassium content among the three chosen fruit peels, but is still considered high. This further demonstrates the potential of mango peel ash as a catalyst.

Fig. 3 shows the SEM images of the banana peel catalyst at a size of 25 nm. The SEM image of the banana peel catalyst shows an amorphous porous structure, similar to that of the mango peel catalyst.

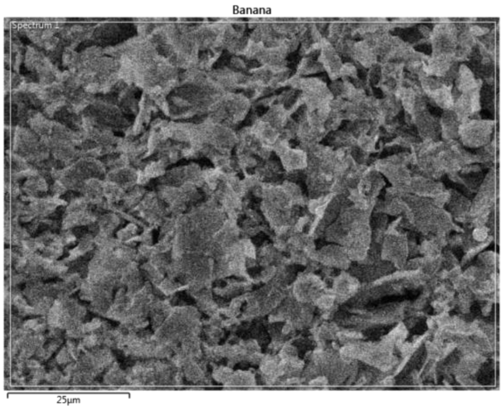

Fig. 3 *SEM image of banana peel ash catalyst*

Table 3 *Chemical composition of banana peel ash catalyst*

Element	Line Type	Weight %	Weight % Sigma	Atomic %
K	K series	52.24	5.57	32.37
Mg	K series	0.15	0.85	0.15
O	K series	42.05	6.10	63.68
Cl	K series	5.56	1.09	3.80
Total		100.00		100.00

7.1 Table 3 shows the composition of the banana peel catalyst. Based on the EDX pattern, the contents of potassium (K) and magnesium (Mg) are 52.24 wt.% and 0.15 wt.%, respectively, which contain the highest amount of Potassium and the lowest amount of Magnesium among the three chosen fruit peels. Both characteristics have proven the potential of the banana peel ash as a catalyst.

7.2 Biodiesel Characterisation

Fig. 4 shows the FTIR results of three different biodiesel samples produced using catalysts from banana, mango, and durian peel, overlaid to illustrate the differences among them. These catalysts were calcined at 600 °C for five hours. The FTIR spectra exhibit similar peaks to those in the previous result from another article. All samples show a strong ester C=O stretch at 1740 cm^{-1}, C-H stretching at 2920 cm^{-1} and 2850 cm^{-1}, and C-O stretching around 1190 cm^{-1}. These peaks confirm successful biodiesel formation [17]. Among them, the banana peel catalyst shows the highest peak at 1740 cm^{-1}, 2920 cm^{-1}, and 2850 cm^{-1}, along with a minimal broad O-H peak (3500 -3200 cm^{-1}), indicating low moisture and high purity [18]. Therefore, the banana peel catalyst is the most efficient catalyst for converting palm oil into biodiesel.

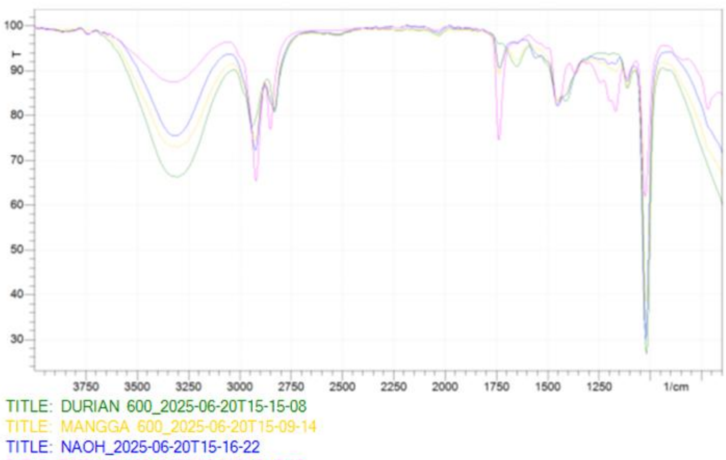

Fig. 4 *FTIR result for biodiesel produced using durian, mango, and banana at 600 °C and NaOH*

4. Conclusion

This study demonstrates how catalysts derived from agricultural wastes, such as banana peel, mango peel, and durian peel, can facilitate the transesterification process to convert palm oil into biodiesel. These findings help provide options in replacing homogeneous catalysts, and researchers might explore various waste that can be turned into something useful and contribute to environmental sustainability. The catalyst shows a significant amount of potassium and magnesium content, which is important for catalytic activity, as confirmed by SEM-EDS analysis. The biodiesel produced also exhibits a functional group consistent with high-quality biodiesel, as verified through FTIR analysis. For example, all the FTIR analyses show a strong peak around 1740 cm^{-1}, indicating C=O and C-O stretch near 1200 – 1000 cm^{-1}. These peaks confirm the presence of Fatty Acid Methyl Esters (FAME), which are the main component of biodiesel. This study successfully demonstrated that these agricultural wastes possess the capacity to serve as a catalyst, based on their chemical composition and surface area, making them a suitable catalyst for various applications. Additionally, the FTIR analysis results indicate that the production of biodiesel is successful, utilising all the waste materials. These results demonstrate that this method provides an environmentally friendly solution for utilising homogeneous catalysts, while also promoting sustainable waste management. Overall, the findings in this report demonstrate the potential of agricultural waste as a primary choice for cost-effective and eco-friendly solutions in biodiesel production.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Aiman Naqib Mohd Fisol, Muhammad Fikri Mohd Sithik, Wan Adam Mukhriz Wan Ahmad Razman, Mohd Khairul Nizam Mohd Zuhan;* ***data collection:*** *Aiman Naqib Mohd Fisol, Muhammad Fikri Mohd Sithik, Wan Adam Mukhriz Wan Ahmad Razman;* ***analysis and interpretation of results:*** *Aiman Naqib Mohd Fisol, Muhammad Fikri Mohd Sithik, Wan Adam Mukhriz Wan Ahmad Razman;* ***draft manuscript preparation:*** *Aiman Naqib Mohd Fisol, Muhammad Fikri Bin Mohd Sithik, Wan Adam Mukhriz Wan Ahmad Razman, Mohd Khairul Nizam Mohd Zuhan. All authors reviewed the results and approved the final version of the manuscript.*

References

Z. I. Rony et al., "*Alternative fuels to reduce greenhouse gas emissions from marine transport and promote UN sustainable development goals*," Fuel, vol. 338, p. 127220, 2023, doi: 10.1016/j.fuel.2022.127220.

W. N. A. Wan Osman, M. H. Rosli, W. N. A. Mazli, and S. Samsuri, "*Comparative review of biodiesel production and purification*," Carbon Capture Sci. Technol., vol. 13, p. 100264, Dec. 2024, doi: 10.1016/j.ccst.2024.100264.

D. Chandran, "*Compatibility of diesel engine materials with biodiesel fuel*," Renew. Energy, vol. 147, pp. 89–99, Mar. 2020, doi: 10.1016/j.renene.2019.08.040.

H. H. Naseef and R. H. Tulaimat, "*Transesterification and esterification for biodiesel production: A comprehensive review of catalysts and palm oil feedstocks*," Energy Convers. Manag.: X, vol. 26, p. 100931, Apr. 2025, doi: 10.1016/j.ecmx.2025.100931.

I. M. Rizwanul Fattah et al., "*State of the art of catalysts for biodiesel production*," Front. Energy Res., Jun. 19, 2020, doi: 10.3389/fenrg.2020.00101.

A. Mukhtar et al., "*Current status and challenges in the heterogeneous catalysis for biodiesel production*," Renew. Sustain. Energy Rev., vol. 157, p. 112012, Apr. 2022, doi: 10.1016/j.rser.2021.112012.

M. K. Bharti, S. Chalia, P. Thakur, S. N. Sridhara, A. Thakur, and P. B. Sharma, "*Nanoferrites heterogeneous catalysts for biodiesel production from soybean and canola oil: A review*," Environ. Sci. Pollut. Res., Oct. 2021, doi: 10.1007/s10311-021-01247-2.

N. Hashim, "*Valorizing durian fruit waste: A path towards functional materials*," Malays. J. Appl. Sci., vol. 10, no. 1, pp. 88–99, Apr. 2025, doi: 10.37231/myjas.2025.10.1.438.

E. K. Sitepu et al., "*Calcined biowaste durian peel as a heterogeneous catalyst for room-temperature biodiesel production using a homogenizer device*," ACS Omega, vol. 9, no. 13, pp. 15232–15238, Apr. 2024, doi: 10.1021/acsomega.3c09642.

M. Amirrul et al., "*Transesterification of waste cooking oil utilizing heterogeneous K_2CO_3/Al_2O_3 and KOH/Al_2O_3 catalysts*," 2021.

L. W. Zhen, S. N. M. Khazaai, G. P. Maniam, and L. Nawi, "*Transesterification of Calophyllum inophyllum oil using CaO–K_2CO_3 catalyst from Corbicula fluminea shells and banana peels (Transesterifikasi minyak Calophyllum inophyllum menggunakan mangkin CaO–K_2CO_3 daripada cangkerang Corbicula fluminea dan kulit pisang)*," 2022.

C. Y. May, "*Transesterification of palm oil: Effect of reaction parameters*," J. Oil Palm Res., vol. 16, pp. 1–11, 2004.

A. J. Asuquo, X. Zhang, L. Lin, and J. Li, "*Green heterogeneous catalysts derived from fermented kola nut pod husk for sustainable biodiesel production*," Int. J. Green Energy, vol. 21, no. 10, pp. 2218–2227, 2024, doi: 10.1080/15435075.2023.2297781.

J. B. Tarigan et al., "*Waste passion fruit peel as a heterogeneous catalyst for room-temperature biodiesel production*," ACS Omega, vol. 7, no. 9, pp. 7885–7892, Mar. 2022, doi: 10.1021/acsomega.1c06785.

V. Khiangte, S. Lalhmangaihzuala, Z. T. Laldinpuii, L. Nunnemi, R. B. Muthukumaran, and K. Vanlaldinpuia, "*Novel dragon fruit peel ash-derived solid catalyst for biodiesel production and PET waste recycling*," Bioresour. Technol. Rep., vol. 24, p. 101663, Dec. 2023, doi: 10.1016/j.biteb.2023.101663.

E. K. Sitepu et al., "*Calcined biowaste durian peel as a heterogeneous catalyst for room-temperature biodiesel production using a homogenizer device*," ACS Omega, vol. 9, no. 13, pp. 15232–15238, Apr. 2024, doi: 10.1021/acsomega.3c09642.

M. F. F. Kamaronzaman, H. Kahar, N. Hassan, M. F. Hanafi, and N. Sapawe, "*Analysis of biodiesel product derived from waste cooking oil using Fourier transform infrared spectroscopy*," Mater. Today Proc., vol. 31, pp. 329–332, Jan. 2020, doi: 10.1016/j.matpr.2020.06.088.

Meriatna, H. Husin, M. Riza, M. Faisal, Ahmadi, and Sulastri, "*Biodiesel production using waste banana peel as renewable base catalyst*," Mater. Today Proc., vol. 87, pp. 214–217, Jan. 2023, doi: 10.1016/j.matpr.2023.02.400.