CURRENT SCIENCE AND TECHNOLOGY
E-ISSN: 2785-8804
VOLUME 4, ISSUE 1, 2024, 51 – 54
DOI: https://doi.org/10.15282/cst.v4i1.11561

RESEARCH ARTICLE

Feasibility of Biodiesel Production from Patty Oil Waste via the Transesterification

N. S. Salehhuddin, M. N. F. Abd Malek*, G. P. Maniam

Faculty of Industrial Sciences and Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, 26300 Kuantan, Pahang, Malaysia

ABSTRACT - Patty oil waste poses significant environmental risks, including land contamination, water pollution, and detrimental effects on plant and animal life if not managed appropriately. To address this issue, the transesterification process offers a sustainable solution for converting patty oil waste into biodiesel, an eco-friendly alternative fuel. This study aims to optimize biodiesel production from patty oil waste using a two-step transesterification process, evaluating its physical and chemical properties. The solid-phase patty oil waste was pretreated and processed using potassium hydroxide (KOH) as a homogeneous catalyst. The initial free fatty acid (FFA) content of the patty oil waste was 6.175%, exceeding the acceptable 5% threshold for direct transesterification. After esterification, the FFA content was reduced to 1.238%, meeting the required specifications. Biodiesel properties were characterized using thin-layer chromatography (TLC) and gas chromatography-mass spectrometry (GC-MS), confirming high methyl ester conversion. The optimal reaction conditions were determined as a KOH concentration of 1.5 wt%, a reaction time of 90 minutes, and a methanol-to-oil molar ratio of 6:1, yielding a maximum methyl ester conversion of 88.47%. The produced biodiesel exhibited properties in compliance with ASTM D6571 standards, including a density of 854 kg/m³, iodine value of 81.24 g/100 g, and acid value of 0.0314 mg KOH/g. This study highlights the potential of patty oil waste as a feedstock for biodiesel production and underscores the efficacy of RSM in optimizing the transesterification process for high-quality biodiesel yield.

ARTICLE HISTORY
Received : 14th Feb. 2024
Revised : 29th Feb. 2024
Accepted : 10th June 2024
Published : 21st June 2024

KEYWORDS
Transesterification
Patty oil waste
Biodiesel

1. INTRODUCTION

The increasing global demand for energy and the rapid depletion of fossil fuel reserves have prompted a growing interest in renewable and sustainable energy sources. Among these, biodiesel has emerged as a viable alternative to petroleum diesel due to its eco-friendly properties, biodegradability, and ability to reduce greenhouse gas emissions. Biodiesel production primarily relies on feedstocks such as vegetable oils, animal fats, and waste oils. However, the high cost of edible oil feedstocks poses a significant challenge, necessitating the exploration of cheaper and more sustainable sources like waste oils [1]. Patty oil waste, a byproduct of food processing and frying activities, is a promising feedstock due to its low cost and abundant availability. Nonetheless, its high free fatty acid (FFA) content often exceeds the permissible threshold for direct transesterification, requiring pretreatment to ensure efficient biodiesel conversion. The improper disposal of patty oil waste (POW) exacerbates environmental issues, including soil contamination, water pollution, and harm to aquatic and terrestrial ecosystems [2]. Consequently, utilizing patty oil waste for biodiesel production presents an opportunity to address waste management challenges while contributing to energy sustainability. Despite its potential, optimizing the biodiesel production process from patty oil waste remains critical to achieving high yield and quality. This study addresses this challenge by employing a two-step transesterification process.

The significance of this study lies in its twofold contribution to environmental and energy sustainability. It offers a practical solution for managing waste palm oil, helping to reduce its harmful environmental effects. Additionally, it demonstrates the feasibility of producing biodiesel that meets ASTM standards, addressing the increasing demand for renewable fuels. This study aims to transform patty oil waste to prepare biodiesel from patty oil waste through two-step transesterification and study the physical properties of biodiesel from patty oil waste.

2. METHODS AND MATERIAL

2.1 Material

The chemicals and solvents used in this study included potassium hydroxide, sulfuric acid, methanol, n-hexane, hydrochloric acid, chloroform, sodium chloride, and ethanol, all of which were sourced from Merck. All reagents were of analytical grade and required no additional purification. Standard potassium hydroxide was obtained from Materya LLC, and a GC-grade internal standard, methyl heptadecanoate, was purchased from Sigma-Aldrich. The materials for this study consisted of patty oil waste collected from local burger stalls in Gambang, Pahang.

*CORRESPONDING AUTHOR | M. N. F. Abd Malek | ✉ mnfazli@umpsa.edu.my

2.2 Transesterification of POW into biodiesel

A total of 100 g of used cooking oil was mixed with methanol in varying ratios of 6:1 at a temperature of 60 ± 5 °C. A homogeneous catalyst, potassium hydroxide (KOH), was then added at different loading percentages of 1.5%. The mixture was heated for a duration of 90 minutes. After heating, the mixture was transferred to a separatory funnel and allowed to sit for 24 hours to facilitate the separation into layers. The upper layer, which contained the biodiesel or methyl ester, was subsequently collected for analysis.

2.3 Methyl Ester Conversion

The fatty acid methyl ester (FAME) concentration in palm oil biodiesel was analyzed using a gas chromatography-mass spectrophotometer (GC-FID) from Shimadzu (model 2010 plus, Japan) with a DB-WAX capillary column (30 m × 0.320 mm × 0.25 μm, Agilent, USA). Methyl heptadecanoic acid (C17:0) was used as the internal standard for this analysis. The composition of FAME was assessed by comparing it to a conventional FAME reference mixture. To calculate the palm oil to biodiesel conversion rate, both before and after the adsorption treatment, Equation (1) was utilized. In this equation, A_{total} represents the total area of the methyl peak, A_{STD} is the area of the internal standard, C_{STD} is the concentration of the internal standard, V_{STD} is the volume of the internal standard, and M_{sample} is the mass of the sample (in mg).

$$conversion = \frac{A_{total} - A_{STD}}{A_{STD}} \times \frac{C_{STD} \times V_{STD}}{M_{sample}} \times 100\% \quad (1)$$

3. RESULTS AND DISCUSSION

3.1 Physical Properties of Biodiesel

Based on the Table 1, the biodiesel produced in this study exhibits favorable properties in terms of acid value, iodine value, and density, meeting the standards outlined in ASTM D6571. The study suggests that the quality of the biodiesel is commendable, adhering to established benchmarks. Despite variations in biodiesel density, the impact of the catalyst on these differences remains inconclusive. It is noteworthy, however, that the density of biodiesel is crucial for emission control, as higher density implies increased mass and potential for elevated emissions upon combustion.

Table 1. Acidity, iodine, and density of FAME

Parameter	Transesterification	ASTM D6571
Acid value (mg KOH/g)	0.0314	Max 0.50
Iodine value (g/1000 g)	81.24	Max 120
Density (kg/m^3) at 40 °C	854	870-900

The influence of the catalyst on the acid value of biodiesel is not clearly established, but the study indicates a correlation between catalyst alkalinity and acid value. The acid value, which reflects the presence of acids in biodiesel, is determined by the percentage of free fatty acids in palm oil waste after the esterification process. This study demonstrates that the catalyst is effective in reducing acid content during esterification, resulting in low acid values that meet ASTM D6571 standards. This finding is supported by previous studies [3-5]. Lower acid values are advantageous because high acid levels can lead to corrosion within the system.

A study on the iodine value of patty oil waste found a value of 81.24 g/1000g, which is well below the maximum limit of 120 set by ASTM D6561. This indicates a lower susceptibility to oxidation, making the oil potentially suitable for applications that require stable and resistant oils [6]. Additionally, the density of the patty oil waste is 854 kg/m³, slightly below the ASTM specified range of 870–900 kg/m³ D6571. While this density remains within acceptable limits, it may require further investigation to understand its impact on energy content variations and the overall performance of the material in specific applications [7] .

3.2 Fatty Acid Methyl Ester Composition

Methyl ester conversion is a quantitative method used to determine the content of Fatty Acid Methyl Esters (FAME). The conversion percentage from patty oil is calculated to be 88.47%. Figure 1 shows the Gas Chromatography-Mass Spectrometry (GC-MS) spectrum of patty oil biodiesel. Using a library search, it is possible to identify and quantify the percentage area of methyl esters in biodiesel.

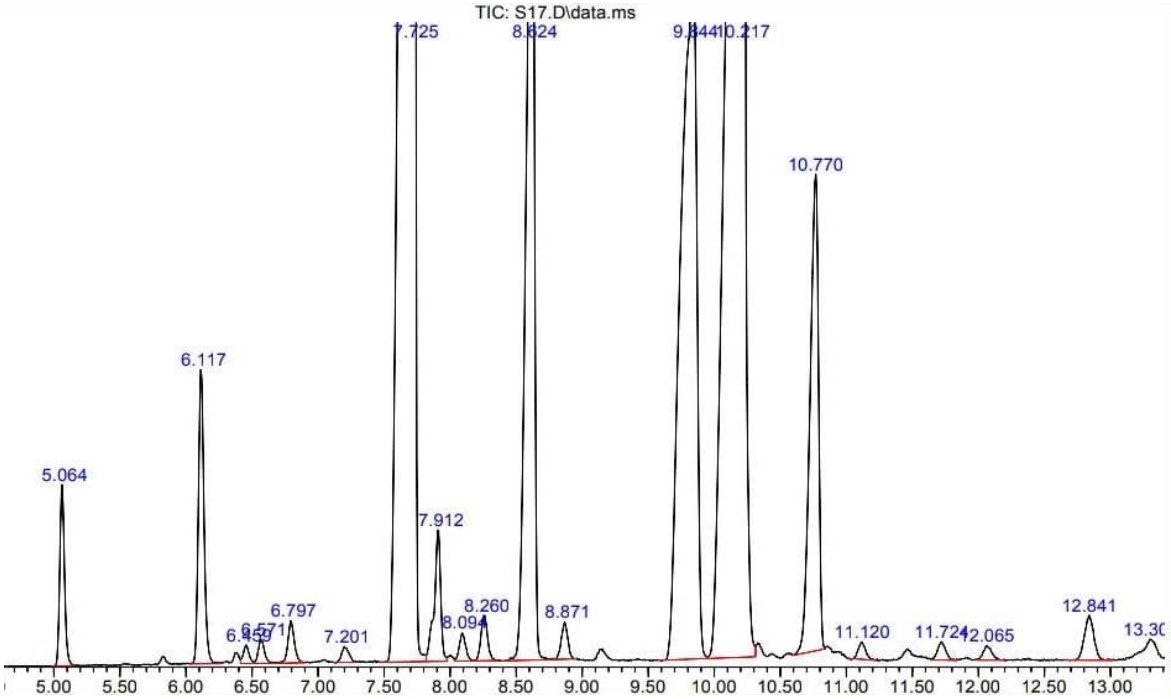

Figure 1. Graph gas-chromatogram mass-spectrometry of free fatty acid

The fatty acid composition under discussion is a mix of saturated and unsaturated fatty acids. As shown in Table 2, palmitic acid dominates the saturated category with a considerable 53.42% contribution, followed by lauratic, myristic, pentadecanoic, arachidic, nonadecyclic, and palmitoleic acids, resulting in for 57.23% of the total composition. On the unsaturated front, oleic acid leads with 36.47%, followed by paullinic, linoleic, and linolenic acids, which make up 42.76% of the mixture. Saturated fatty acids, especially palmitic acid, help biodiesel maintain its oxidative stability. Biodiesel with a higher percentage of saturated fatty acids is frequently more resistant to oxidation, extending its shelf life. However, the trade-off of perhaps higher cloud points and worse cold-flow characteristics limits its application in colder areas. In contrast, biodiesel performs better in colder climates when it contains unsaturated fatty acids like oleic acid, which have lower cloud points. Biodiesel that contains a high concentration of unsaturated fatty acids is more prone to oxidation, which could eventually cause stability problems.

Table 2. Composition of free fatty acid in biodiesel

Free Fatty Acid	Structure	Composition (%)
Lauratic	12:0	1.17
Myristic	14:0	0.20
Pentadecanoic	15:0	0.51
Palmitic	16:0	53.42
Palmitoleic	16:1	1.17
Oleic	18:1	36.47
Linoleic	18:2	5.71
Linolenic	18:3	0.20
Nonadecyclic	19:0	0.17
Arachidic	20:0	0.59
Paullinic	20:1	0.80
Total saturated fatty acid	-	57.23
Total unsaturated fatty acid	-	42.76

4. CONCLUSION

This study successfully produced biodiesel from patty oil waste that meets ASTM D6571 standards, demonstrating excellent quality and sustainability. The biodiesel's acid value, iodine value, and density are favorable, with the acid value effectively reduced through esterification, minimizing risks of engine corrosion. The iodine value of 81.24 g/1000 g indicates good oxidative stability, while the density of 854 kg/m³, though slightly below the ASTM range, remains acceptable for practical use. The biodiesel achieved an 88.47% fatty acid methyl ester (FAME) conversion, with a composition of 57.23% saturated and 42.76% unsaturated fatty acids. The high saturated fat content ensures oxidative

stability and longer shelf life, while unsaturated fats enhance cold-flow properties, making the biodiesel versatile for different climates. However, the trade-off between stability and cold-weather performance requires further investigation. In conclusion, the optimized process for biodiesel production from patty oil waste shows great potential for producing a sustainable, high-quality alternative fuel. Future work should address density variations and improve both stability and cold-weather performance for broader applications.

ACKNOWLEDGEMENTS

This work was supported by UMPSA Fundamental Research Grant (RDU230374)

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest associated with this research. All experiments, analyses, and interpretations were conducted impartially and without any financial, personal, or professional influences that could have affected the outcomes or conclusions of the study.

AUTHORS CONTRIBUTION

All authors have significantly contributed to the completion of this research and the preparation of the manuscript.

N. S. Salehhuddin (Conducted the laboratory experiments, collected data, and performed data analysis.)

M. N. F. Abd Malek (Conceptualization; Investigation; Supervision)

G. P. Maniam (Investigation; Resources; Funding acquisition)

REFERENCES

[1] A. S. Elgharbawy, W. Sadik, O. M. Sadek and M. A. Kasaby, "A review on biodiesel feedstocks and production technologies,". *Journal of the Chilean Chemical Society*, vol. 66, no. 1, pp. 5098-5109, 2021.

[2] N. A. Hamdi, S. Sha'Arani, N. F. Azman, S. B. M. Rafi, E. Norsin and N. Othman, "Management of waste cooking oil and its potential for value-added materials: A mini review," In *IOP Conference Series: Earth and Environmental Science*, vol. 1091, no. 1, p. 012054, 2022

[3] M. C. Hsiao, P. H. Liao, N. V. Lan and S. S. Hou, "Enhancement of biodiesel production from high-acid-value waste cooking oil via a microwave reactor using a homogeneous alkaline catalyst," *Energies*, vol. 14, no. 2, p. 437, 2021.

[4] Z. Weng, Y. Tao, H. Fei, W. Deng, Y. Chen, Z. Zhao, et al., "Green production of biodiesel from high acid value oil via glycerol esterification and transesterification catalyzed by nano hydrated eggshell-derived CaO," *Energies*, vol. 16, no. 18, p. 6717, 2023.

[5] G. P. Maniam, H. S. Lim and N. M. Hussin, "Effect of free fatty acid on transesterification of waste cooking oil," *Current Science and Technology*, vol. 3, no. 1, pp. 57-63, 2023.

[6] Y. Huang, F. Li, G. Bao, M. Li and H. Wang, "Qualitative and quantitative analysis of the influence of biodiesel fatty acid methyl esters on iodine value," *Environmental Science and Pollution Research*, vol. 29, no. 2, pp. 2432-2447, 2022.

[7] D. Unlu, N. Boz, O. Ilgen and N. Hilmioglu, "Improvement of fuel properties of biodiesel with bio additive ethyl levulinate," *Open Chemistry*, vol. 16, no. 1, pp. 647-652, 2018.