PRINT ISSN 1119-8362
Electronic ISSN 2659-1499

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 28 (5) 1461-1466 May 2024

Characterization of Palm Fatty Acid Distillate and Soybean Deodorized Distillate for Biodiesel Production

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ABSTRACT: Palm fatty acid distillate (PFAD) and soybean deodorized distillate (SDD) are two prominent byproducts in the vegetable oil industry; hence, the objective of this paper was to characterize the physicochemical properties of palm fatty acid distillate (PFAD) and soybean deodorized distillate (SDD) biodiesel production. Various physicochemical properties, including fatty acid composition, acid value, iodine value, saponification value, and viscosity, underwent analysis. Moreover, the study identified impurities like moisture, free fatty acids, and unsaponifiable matter. This thorough assessment offers essential insights into the materials' suitability for biodiesel production, thus informing potential industrial applications. It underscores the significance of selecting appropriate feedstocks in biodiesel manufacturing, ensuring optimal quality and efficiency. By considering these factors, stakeholders can make informed decisions regarding material sourcing and processing methods, ultimately enhancing overall production outcomes. Additionally, this evaluation facilitates the identification of potential challenges and opportunities in the biodiesel industry, contributing to informed decision-making and strategic planning. Furthermore, the potential environmental and economic benefits of utilizing these byproducts in biodiesel production are discussed.

DOI: https://dx.doi.org/10.4314/jasem.v28i5.17

Cite this Article as: ESAN, A. O; BABALOLA, B. A; RAJI, Y. A; OLADIGBOLU, M. A; AJAO, G. Q; OLAWOORE, I. T; ADEYEMI, A. D. (2024). Characterization of Palm Fatty Acid Distillate and Soybean Deodorized Distillate for Biodiesel Production. *J. Appl. Sci. Environ. Manage.* 28 (5) 1461-1466

Dates: Received: 21 February 2024; Revised: 22 March 2024; Accepted: 20 April 2024 Published: 09 May 2024

Keywords: Palm fatty acid distillate; soybean deodorized distillate; biodiesel; energy

Energy stands as an indispensable requirement for human survival. Globally, many nations are embracing biodiesel technology as a remedy for the continuous surge in fuel costs caused by the diminishing reserves of non-renewable fossil fuels and the widespread problem of environmental pollution (Gielen *et al*., 2019). This surge in research aims to find alternative fuels to replace traditional petroleum-based ones, with biodiesel standing out as a leading contender. Biodiesel, sourced from vegetable oils and animal fats, offers a renewable energy solution. Biodiesel, a renewable and environmentally friendly alternative to traditional diesel fuel, is typically derived from natural sources such as vegetable oils, animal fats, or recycled cooking oils (Topare *et al*. 2022). Using a chemical process called transesterification, the triglycerides present in these materials react with alcohol (typically methanol or ethanol) in the presence of a catalyst, resulting in the production of biodiesel and glycerin. This biodiesel variation can power diesel engines

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seamlessly with minimal modifications, offering performance comparable to conventional diesel while emitting fewer harmful pollutants like sulfur dioxide and particulate matter (Kosuru *et al*., 2024). Its sustainable and low-emission characteristics position biodiesel as a crucial component in the advancement of green energy solutions. Trans-esterification is a chemical process involving the exchange of ester groups among molecules (Ameen *et al.,* 2022). Typically, it entails the interaction between an alcohol and an ester with the aid of an acid or base catalyst. During this process, the ester bond within one molecule is severed, while a new ester bond forms with another alcohol molecule, resulting in the production of a different ester (Mandari and Devarai 2021). This reaction is extensively utilized in biodiesel production, wherein triglycerides sourced from vegetable oils or animal fats undergo trans-esterification with alcohol, yielding fatty acid methyl or ethyl esters, crucial components of biodiesel. Moreover, trans-esterification holds significant importance across various industries, including pharmaceuticals, cosmetics, and food, enabling the tailoring of ester compounds to meet specific application requirements. Derived from plants such as soybean, palm, and canola, edible oils have emerged as vital components in biodiesel production, providing a sustainable alternative to fossil fuels (Salimon *et al*., 2012). This transition addresses environmental concerns and reduces dependence on limited resources. Through transesterification, these oils can be transformed into biodiesel, offering a cleaner fuel alternative with lower greenhouse gas emissions.

The integration of edible oils into biodiesel production marks a significant step towards enhancing energy security and promoting environmental sustainability in the transportation sector (Mahapatra *et al.,* 2021). Non-edible oils are prioritized for biodiesel production over edible oils to tackle ethical concerns regarding food security and environmental sustainability. By using non-edible oils, competition with food resources is alleviated, lowering the risk of food price inflation and advancing a more sustainable approach to biodiesel production (Benti *et al.,* 2023). Non-edible oils extracted from plants such as jatropha and pongamia, alongside waste cooking oils like Palm Fatty Acid Distillate and Soybean Deodorized Distillate, offer numerous advantages compared to their edible counterparts. These oils are sourced from plants or processes unsuitable for human consumption, addressing concerns regarding food scarcity and competition (Demirbaş *et al*., 2016). Moreover, their utilization contributes to sustainability by repurposing waste materials and reducing dependence on finite resources. Additionally, waste cooking oils like Palm Fatty Acid Distillate and Soybean Deodorized Distillate repurpose byproducts from food processing, thereby reducing environmental impact. Incorporating non-edible oils into biodiesel production not only helps mitigate environmental challenges linked to traditional fuels but also bolsters rural economies by generating new revenue streams (Nair *et al*., 2022). This transition underscores a commitment to sustainable energy solutions, fostering a more resilient and environmentally aware future. Palm Fatty Acid Distillate (PFAD) emerges as a valuable byproduct of the palm oil refining process, distinguished by its high content of free fatty acids (FFAs) and triglycerides. Its potential for use in biodiesel production has garnered significant interest due to its wide availability and cost-effectiveness (Top, 2010). PFAD contains a notable proportion of both saturated and unsaturated fatty acids, making it a viable feedstock for biodiesel synthesis. Through the process of transesterification, PFAD can be transformed into biodiesel, offering a renewable and environmentally friendly substitute for conventional diesel fuel. Biodiesel derived from PFAD showcases advantageous characteristics such as a high cetane number and minimal sulfur content, contributing to emissions reduction and improved engine performance (Esan *et al*., 2021).

Furthermore, its utilization as a precursor for biodiesel production promotes sustainability by repurposing a waste product, thereby enhancing both the economic and environmental sustainability of the palm oil industry. With ongoing advancements in research and technology, the incorporation of PFAD into biodiesel production processes holds promising prospects for meeting the rising global demand for renewable energy alternatives (Loh *et al*., 2021). .Soybean deodorized distillate (SDD) is a valuable byproduct obtained during the soybean oil refining process. Its high lipid content and favorable fatty acid composition make it an attractive resource for biodiesel production. Notably, SDD contains fewer free fatty acids compared to raw soybean oil, which simplifies biodiesel production by reducing the need for extensive pre-treatment. Moreover, the deodorization process removes unwanted odors and flavors, enhancing the overall quality of the resulting biodiesel (Visioli *et al*., 2016).

Utilizing SDD as a biodiesel feedstock not only repurposes a previously discarded byproduct but also promotes sustainability within the biodiesel industry. Its ready availability as a byproduct of soybean oil refinement emphasizes its cost-effectiveness and environmental friendliness, aligning well with the increasing demand for renewable and sustainable energy solutions (Gbadeyan *et al*., 2024). Hence, the objective of this paper was to characterize the physicochemical properties of palm fatty acid distillate (PFAD) and soybean deodorized distillate (SDD) biodiesel production.

MATERIALS AND METHODS

Samples and Reagent used: All the chemicals, reagents, and solvents used in this research were sourced from Rovet Chemical Nigeria Limited. PFAD (Palm Fatty Acid Distillate) was collected from palm oil refining, and SODD (Soybean Deodorize Distillate) was obtained from the soybean refining process located at Keresa Mill Sdn Bhd, Sarawak, Malaysia.

Physicochemical parameters: The physicochemical parameters, including Acid value, Free fatty acid content, Peroxide value, Saponification value, and Iodine value, of both PFAD and SODD were assessed using various standardized methods

Free fatty acid: The determination of Free Fatty Acids (FFA) was conducted according to the AOCS official method. Typically, 1-2 grams of SODD and PFAD were accurately weighed and placed into a 250mL Erlenmeyer flask. Subsequently, 20mL of neutralized ethanol was added to the sample in the presence of phenolphthalein indicator. The solution was then heated and titrated with a standardized KOH solution from the burette.

Acid value: The acid value was determined following the method outlined by Putri et al. (2020). Accurately about (10.688g of SODD and 10.583g of PFAD) was weighed into 250mL conical flask, 25mL of neutralized ethanol was added into each sample, and the mixture was titrated with 0.1M sodium hydroxide using phenolphthalein as indicator

Peroxide value: The method outlined by Indah et al. (2022) was used to determine the peroxide value (PV). Initially, 11.836g of SDD and 11.900g of PFAD were dissolved in 30ml of glacial acetic acid (CH_3COOH) mixed with chloroform ($CHCl_3$) in a 3:2 ratio. Following this, 0.5mL of potassium iodide was added, and the mixture was allowed to stand for five minutes. Next, 30mL of distilled water was added, and the resulting solution was titrated with 0.1M sodium thiosulfate until reaching the endpoint. Finally, 1mL of soluble starch was introduced as an indicator to complete the titration process.

Saponification Value: The saponification value was determined according to the method described by Varona et al (2022). Approximately 5.18g of SDD and 5.60g of PFAD were individually weighed into separate round bottom flasks, and 50ml of ethanolic potash was added to each flask. A blank solution was prepared by adding the same amount of ethanolic potash without the oil sample. All flasks were then placed in a water bath and boiled for 60 minutes. The titration was carried out using 0.5N HCl, with phenolphthalein indicator present. Each sample underwent two rounds of titration.

Iodine value: The iodine value determination followed the protocol outlined by Yusuf et al. (2015). Initially, 25 ml of Wijs solution was dissolved in carbon tetrachloride. Then, separately, 2.700g of SODD and 2.850g of PFAD were added. The resulting mixture was allowed to stand in darkness at 25°C for 2 hours. Additionally, 20 ml of 1% KI solution was introduced, followed by titration with 0.1N sodium thiosulphate using starch as an indicator. The procedure for determining the blank solution mirrored these steps.

RESULTS AND DISCUSSION

Table 1 shows the physiochemical parameters of PFAD and SDD such as free fatty acid value, iodine value, peroxide value, saponification value. The results indicates that the soybean deodorize distillate (SDD) has higher characterized parameters compared to the palm fatty acid distillate (PFAD), except for the saponification value which is higher in palm fatty acid distillate (PFAD) (Jimenez-Moya *et al*., 2021). Free fatty acids are considered impurities due to their potential negative impact on the transesterification process. Lower FFA composition of 54.66±0.01 for the PFAD indicates that the PFAD requires less refining compared to the FFA composition for the SDD oil which shows 70.54±0.02 indicating that the oil requires more refining for biodiesel feedstock (Bouaid *et al*., 2016). Acid value is another parameter which indicates the amount of KOH needed to neutralize one gram of oil, it also shows the level of acidity of free fatty acid present in the feedstock which can lead to high corrosiveness in biodiesel feedstocks. A comparison of acid values between PFAD and SDD oils reveals significant differences in acidity levels (Sharma and Jain, 2015). The PFAD has lower acid value of 109.33±0.01 showing low level of corrosiveness. In contrast, SDD oil has higher acid values of 141.09±0.02, indicating higher level of corrosiveness which implies that the biodiesel produced from this feedstock will be more corrosive than the fuel produced from the other feedstock which is PFAD (Li *et al*., 2024). This also suggests that SDD may require more neutralization processes to reduce the acidity. Consequently, suggesting PFAD more suitable for the production of biodiesel due to its low acid level (Pisarello *et al*., 2010). Peroxide value (PV) in biodiesel indicates oxidative rancidity, affecting flavor, color, and shelf life. High PV levels also impair engine performance and may violate regulatory standards. Proper storage, processing, and monitoring are essential to manage PV and maintain biodiesel quality (Gotoh & Wada, 2006). PFAD and SDD oils have peroxide values of 26.30±0.01 and 54.05±0.01, respectively. Higher peroxide values implies increased level of oxidation and rancidity. SDD oil has a significantly higher peroxide value compared to PFAD oil, suggesting potential lower quality and stability. Differences in processing methods, raw materials, or storage conditions may account for this variance. Monitoring acid values is crucial for assessing oil quality and for applications.

The saponification value indicates the KOH required to saponify fat or oil, crucial for estimating triglyceride molecular weight and biodiesel properties. It determines the transesterification catalyst and assesses feedstock purity for quality control, ensuring compliance with standards (Ivanova *et al*., 2022). PFAD exhibits an saponification value of 145.38 ± 0.03, indicating longer free fatty acid chain and suggesting less refinement compared to SDD, which has a lower saponification value of 126.82 ± 0.02. This contrast implies that PFAD's longer chain is due to minimal refinement, while the lower saponification values of SDD suggest superior quality and stability. The iodine value determination indicates the unsaturation level in oil samples. A higher iodine value signifies a greater concentration of unsaturated fatty acids. For instance, PFAD has an iodine value of 41.88±0.01, indicating a low level of unsaturation predominantly consisting of saturated fatty acids. In contrast, SDD oil, with an iodine value of 97.26±0.01, exhibits significantly higher unsaturation, suggesting a richer composition of unsaturated fatty acids. Due to its higher unsaturation, SDD oil likely offers improved fluidity and oxidative stability compared to PFAD.

Table 1: The result of physiochemical parameters of Palm Fatty Acid Distillate (PFAD) and Soybean Deodorized Distillate (SDD)

Parameters	PFAD	SDD
Free fatty acid	54.66±0.01	70.55±0.02
Acid Value	109.33±0.01	141.09±0.02
Saponification Value (KOH/g)	145.38±0.03	126.82±0.02
Iodine Value	41.88±0.01	97.26±0.01
Peroxide Value	26.30±0.01	54.05±0.01

Conclusion: This study explores the viability of Palm Fatty Acid Distillate (PFAD) and Soybean Deodorized Distillate (SDD) as biodiesel feedstocks. PFAD and SDD, derived from palm oil and soybean oil refining, respectively, are investigated for their physicochemical properties and fatty acid composition. The analysis assesses parameters like acid, iodine, saponification, and peroxide values to gauge compliance with biodiesel standards. PFAD shows higher saturated fatty acid levels, notably palmitic acid, while SDD exhibits more unsaturated fatty acids, mainly linoleic and oleic acids. PFAD also demonstrates lower acidity and higher viscosity compared to SDD. These differences highlight the distinct characteristics of each feedstock and their potential impact on biodiesel production and fuel properties amid increasing demand for sustainable alternatives to fossil fuels.

Acknowledgements: The authors acknowledge the support of the African-German Network of Excellence in Science (AGNES) and TETFUND LAUTECH Institution Based Research Grant.

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