Assessment and Characterization of Biodiesel Production from Blended Oils Using Transesterification Technology

Ofor, Helen Obianuju (Ph.D.), Obiwuru Chisom Modesta

Science Laboratory Technology Department, Federal University of Petroleum Resources Effurun, Delta State Nigeria

DOI: https://doi.org/10.51244/IJRSI.2026.1305000169

Received: 14 May 2026; Accepted: 19 May 2026; Published: 06 June 2026

ABSTRACT

The study investigated the effects of blended groundnut oil and coconut oil using potassium hydroxide (KOH) as a catalyst through the transesterification process to improved fuel properties by evaluates the physicochemical characteristics of the produced biodiesel (Fatty Acid Methyl Esters – FAME), and compared them with standard biodiesel specifications; the properties including density, viscosity, acid value, flash point, and moisture content. Fourier Transform Infrared Spectrophotometer (FTIR) was used to detected the changes in the functional groups of the raw and carbonized biodiesel samples and the formation of ester bonds in each biodiesel sample, which directly influences the fuel properties. The feed-stocks used in this researched were raw, unrefined groundnut oil and coconut oil, both sourced from local processors in Lokoja, Kogi State and were freshly extracted, filtered to removed impurities and were divided into three broad groups. The findings indicated that the blended oil biodiesel exhibited improved fuel quality within acceptable biodiesel standards, also vital for FAME of biodiesels production especially in Nigeria where feed stock are very available; also, biodiesel production from these feed-stocks can serve as an alternative renewable and environmentally friendly alternative to fossil diesel.

Keywords: Biodiesel, blended edible oil, FTIR, flash point, moisture content

INTRODUCTION

The transition from fossil-based fuels to renewable sources such as biodiesel is essential for achieving energy security, environmental sustainability, and economic development. This perspective supports the choice of biodiesel production as a means of reducing greenhouse gas emissions. In Nigeria, groundnut oil and coconut oil are readily available feedstocks for biodiesel production. Groundnut oil is high in unsaturated fatty acids, providing good combustion properties but lower oxidative stability. Coconut oil, by contrast, is highly saturated, offering stability but relatively poor cold-flow properties. The composites of these two oils provide an opportunity to combine their strengths and mitigate their weaknesses, thereby producing biodiesel with balanced properties (Ofor et al 2021, 2023, 2024). To achieve this, a catalyst is necessary to promote the transesterification reaction. The transesterification reaction provides the chemical foundation for biodiesel production. In this process, triglycerides contained in vegetable oils react with a short-chain alcohol, typically methanol, in the presence of a catalyst such as KOH.

METHODOLOGY

Sample Collection

The feed-stocks used in this researched were raw, unrefined groundnut oil and coconut oil, both sourced from local processors in Lokoja, Kogi State. A total of 3 liters of each oil type was collected. The oils were freshly extracted, filtered to removed impurities, and stored in airtight containers prior to the transesterification process to prevent oxidation.

Materials, Equipment and Reagent

The materials and equipment used for this study were divided into three broad groups. Groundnut oil and coconut

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue V May 2026

oil (raw, unrefined) were the feed-stocks used for biodiesel production; blended together to enhance the biodiesel properties. Equipment used were Fourier Transform Infrared Spectroscopy (FTIR) Sample prep: Biodiesel mixed with KBr (1:100) and pressed into pellets. Purpose: To identify functional groups and verify conversion of triglycerides to esters. Beakers, and measuring cylinders, magnetic stirrer, separating funnel, distillation unit, filter papers, funnel and airtight storage containers. Chemicals and reagents used were potassium hydroxide (KOH), Methanol (CH_3OH), Isopropyl alcohol/toluene, Phenolphthalein indicator and distilled water.

Experimental Procedure

Pre-treatment (Filtration of Oils): A significant amount of both oils was filtered using a filter paper to removed particles and collected in a round bottom flask.

Preparation of Feed-stocks (Oils): A significant amount of both the groundnut oil and coconut oil was poured into two different beakers. Then, a mixture of both the groundnut oil and coconut oil were prepared and then mixed in three different beakers using three different ratios. Each beaker contained a mixture of both groundnut oil and coconut oil but with different blending ratios. The mixed oils were gently stirred using a stirring rod and heated with a hot plate at 50 °C for 20 minutes to reduce viscosity. The blending ratios were as follows:

Sample A (80:20): 80% groundnut oil, 20% coconut oil with a volume ratio of 80 ml groundnut oil and 20 ml coconut oil, totaling 100 ml.

Sample B (70:30): 70% groundnut oil, 30% coconut oil with a volume ratio of 70 ml groundnut oil and30 ml coconut oil, totaling 100 ml.

Sample C (60:40): 60% groundnut oil, 40% coconut oil with a volume ratio of 60ml groundnut oil and 40 ml coconut oil, totaling 100 ml.

Catalyst Solution Preparation (KOH in Methanol):4.5g of KOH pellets was dissolved immediately in the 100 ml of methanol placed in a conical flask. The mixture was stirred continuously with a glass rod until the KOH pellets dissolved completely, forming a methoxide solution.

Transesterification Process: 8.5 ml of the methoxide solution was measured and transferred into each of the three small beakers containing the blended oils (Samples A, B, and C). The reaction was maintained for 2 hours. The temperature was monitored using a 100 °C thermometer throughout the process. After 2 hours, the reaction was stopped and the mixture was allowed to cool for 30 minutes before being transferred into a separating funnel. The same procedure was repeated for Samples B and C.

Separation of Biodiesel (Phase Separation): Each of the three samples were placed into different separating funnels and allowed to settle for 24 hours. After 24 hours, two distinct layers observed:

Upper layer: Biodiesel (Fatty Acid Methyl Esters – FAME), lighter in color.

Lower layer: Glycerol, denser and darker in color.

Washing and Purification of Biodiesel: Each biodiesel sample obtained was washed with distilled water to remove impurities. After washing, each sample was allowed to separate in a separating funnel. The biodiesel phase was filtered using filter paper to remove soap residues. Drying was then carried out by heating at 110 °C to remove residual moisture. Finally, the biodiesel was stored in clean, dry containers before testing.

Reaction Scheme for Transesterification:

Triglycerides (Groundnut oil + Coconut oil blend) + 3 CH_3OH → 3 R-$COOCH_3$ (Biodiesel, FAME) + $C_3H_5(OH)_3$ (Glycerol) (KOH catalyst, 50–60 °C, 2 hrs.)

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue V May 2026

Method of FTIR Analysis

Fourier Transform Infrared Spectrophotometer (FTIR) was used to detect the changes in the functional groups of the raw and carbonized biodiesel samples. The analysis was performed on an Infrared Spectrometer Varian 660 MidIR Dual MCT/DTGS Bundle with ATR detector, operating at a resolution of 4 cm-1 with 200 scans per sample. Spectra were recorded in the frequency range of 4000 cm-1 to 500 cm-1. For sample preparation, the biodiesel samples were finely ground and mixed with potassium bromide (KBr) in a ratio of 1:100. The mixture was pressed in a die under a load of 10 tons to form a 13 mm pellet, which was then inserted into the FTIR sample chamber. Potassium bromide was used as a reference material since it does not interfere within the infrared window of 400–4000 cm-1. The pellet was washed three times with 10 ml of deionized water to remove any free proteins or enzymes not bound to the samples. The samples were dried, re-ground with KBr, and analyzed. The reference KBr also served as the baseline for plotting the transmittance axis in the FTIR graph. Data acquisition was managed using IR solution software, which produced spectra as plots of transmittance versus wavelength. A value of 0 % transmittance indicated total absorption of radiation by the sample, while 100% transmittance indicated no absorption relative to the reference. Each spectrum generated was unique for the sample analyzed and was used to identify the functional groups present in the biodiesel.

Physicochemical Properties of Biodiesel

Moisture Content: Moisture content of the sample was done by weighing the sample before and after heating for an hour after which the difference in weight were recorded.

$$\% \text{ Moisture Content} = (W1 - W2) / W1 \times 100 \quad (1)$$

Where: W1 = weight of sample before heating inside an oven W2 = weight of sample after heating 25.

Density: The density of the sample was measured by measuring the empty pycnometer weight and the weight was recorded. 50 ml of sample was poured into the pycnometer and weighed to determine the density according to the equation below:

$$\text{Density} = \text{Sample weight Sample volume} \quad (2)$$

Kinematic Viscosity: The viscosity was measured at two different temperatures (40 °C). At the beginning a proper viscometer spindle was selected. The sample was transferred to a beaker and placed on a heating mantle which was set to heat to about 45 °C. The spindle was immersed into the sample and the viscometer was turned on and allowed to calibrate and stabilize after which the reading displayed on the screen was taken at 40 °C and recorded. The kinematic viscosity of the sample was determined by the equation below:

$$\text{Kinematic Viscosity} = \text{Reading obtained} \times \text{Spindle speed factor} \quad (3)$$

Acid Value: The acid value measurement was carried out according to ASTM-D664 method. A solvent consisting of isopropyl alcohol and toluene 50% each was properly prepared in a beaker of 600 ml. 2 g of the sample was added to the beaker followed by 2 drops of phenolphthalein indicator. The solution was titrated with KOH (0.1 M) until the color changed to pink. The acid value was calculated using the equation:

$$\text{Acid Value} = (56.1 \times M) / \text{Sample weight} \quad (4)$$

Where: M = molarity of KOH 56.1 = molecular weight of KOH 26

Flash Point: Flash point is the lowest temperature at which the biodiesel ignited in the presence of a fire source.

RESULTS AND DISCUSSIONS

The characterization was conducted using multiple analytical techniques to provide a comprehensive assessment. Fourier Transform Infrared (FTIR) spectroscopy was employed to identify functional groups, confirming the presence of ester bonds could indicate of successful transesterification by characterization of each of the sample

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue V May 2026

at different ratio of sample A (80:20), sample B (70:30) and sample C (60:30) groundnut oil and coconut oil feed-stock. Physicochemical properties, including kinematic viscosity, acid value, density, flash point, and moisture content, were measured using ASTM methods to evaluate compliance and provided insights into production consistency and process optimization needs with industry standards and suitability for diesel engines (Ofor et al., 2025 and 2026), Also descriptive statistical analysis was performed to assess variability in FAME composition. The different variations of the values were recorded in the tables below.

Table 1: Characteristic FTIR Absorption Peaks for Biodiesel Samples

Run	Peak Wavelength (cm^{-1})	Transmittance (%)	Assignment	Functional Group
1	3400.19	44.36	O–H stretching vibrations	Hydroxyl group
2	3006.54	54.18	C–H stretch vibration in unsaturated hydrocarbon	Aromatic group
3	2958.27	57.06	C-H stretches vibrations in CH_3/CH_2 group	Aliphatic compound
4	1740.98	68.43	C=O stretch vibrations in ester	Ester carbonyl
5	1465.46	62.37	C-H scissoring vibration	Methyl group
6	1377.09	61.19	C-H bending in FAMES	Methylene group
7	1265.83	57.64	C–O stretch vibrations in Methyl esters	Ester group
8	1171.58	63.81	C–O–C / C–O Stretch vibrations	Ether group
9	1100.40	63.62	C–O / C–C stretch vibrations	Alcohol/ester group
10	820.45	57.48	C-H rocking vibrations	Long-chain methylene

Table 2a. Physicochemical Results *for Biodiesel Samples*

S/N	Analysis	Sample A Result	Sample B Result	Sample C Result
1	Viscosity mm^2/s @40^OC	5.89	4.97	5.37
2	Acid Value mgKOH/g	0.49	0.37	0.43
3	Density	0.87g/cm^3or 870kg/m^3	0.83 g/cm^3or 830kg/m^3	0.85 g/cm^3 or 850kg/m^3
4	Flash point ^OC	138	142	135
5	Moisture Content %	0.06	0.08	0.07

Table 2b. US and EU Biodiesel Specifications on Physicochemical Parameters

	Analysis	ASTM D6751	EN 14214
1	Viscosity mm^2/s @40^OC	1.9 – 6.0	3.50 – 5.0
2	Acid Value mg KOH/g	0.50	0.50
3	Density	860- 900kg/m^3	860- 900kg/m^3
4	Flash point ^OC	93 ^OC	101 ^OC
5	Moisture Content %	0.05% vol	500mg/kg

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue V May 2026

The feedstock ratios sample A (80:20), sample B (70:30) and sample C (60:30) were designed to explore the impact of blending groundnut and coconut oils, which differ in their fatty acid profiles (e.g., coconut oil is rich in lauric acid, while groundnut oil contains more unsaturated fatty acids).

Fourier Transform Infrared (FTIR) Spectroscopy Analysis:

FTIR analysis was employed to confirm the successful transesterification of the feedstock into biodiesel by identifying characteristic functional groups and noting the disappearance of peaks associated with triglycerides. The FTIR spectra in table 1 for all three samples (A, B, and C) showed prominent absorption bands characteristic of biodiesel (FAMEs). Key peaks and their assignments were summarized at the Table 1 and discussed below:

- O-H Stretch (3200-3600 cm^{-1}): The broad peaks observed in all samples are indicative of residual moisture or glycerol, common byproducts in biodiesel that require purification.
- C-H Stretch (2850-3000 cm^{-1}): The strong peaks between 2853 and 2958 cm^{-1} are attributed to symmetric and asymmetric stretching of CH_2 and CH_3 groups, representative of the long aliphatic chains presents in FAMEs.
- C=O Stretch (~1740 cm^{-1}): This very strong and sharp peak is the most significant, confirming the presence of ester carbonyl groups (O-C=O), which is the definitive functional group in biodiesel.
- C-O Stretch (1000-1300 cm^{-1}): The strong peaks in this region further validate the presence of ester linkages, resulting from the transesterification reaction.

The FTIR spectra of biodiesel Samples A (80:20), B (70:30), and C (60:40) exhibited similarity when compared, indicating a consistent chemical composition dominated by fatty acid methyl esters (FAMEs). The presence of characteristic peaks, such as the strong C=O stretch at ~1740 cm^{-1} and C-O stretch at 1000–1300 cm^{-1}, confirms successful transesterification across all samples; these indicates the present of ester functional groups typical of biodiesel. Although, there were insignificant differences in peak intensities, particularly in the O-H stretch region (3200–3600 cm^{-1}), suggest variations in purification efficiency, residual glycerol, or moisture content, which are influenced by the feedstock ratios and processing conditions.

The different spectral noticed among the samples was at the stronger O-H stretch peak in Sample A (80:20) at 3400.19 cm^{-1} with a transmittance of 44.36%, compared to Sample B (3500.98 cm^{-1}, 62.11%) and Sample C (3200.98 cm^{-1}, 42.52%). This broader and more intense of O-H peak in Sample A suggested higher concentration of residual glycerol or moisture; commonly byproducts of biodiesel production (Ofor *et al.*, 2026). The higher O-H intensity in Sample A may be attributed to its feedstock ratio (80:20), highly proportional of oils with greater free fatty acid content were washed more to removed glycerol (Ofor *et al.*, 2026). While Sample B's weaker O-H peak suggests more effective purification, possibly due to its 70:30 ratio, which may balance the feedstock oils to minimize byproduct retention.

Sample C, with a 60:40 ratio, shows an O-H peak intensity similar to Sample A, indicating comparable challenges in purification. However, Sample C also exhibits a slightly stronger C=O peak (1740.31 cm^{-1}, 68.14%) compared to Sample A (1740.98 cm^{-1}, 68.14%) and Sample B (1740.45 cm^{-1}, 64.34%), suggesting a higher ester content. This indicated transesterification in Sample C, potentially due to an optimal balance of feedstock oils that enhances catalyst activity or reaction kinetics. Residual glycerol or moisture present indicated by the O-H peaks, has significant implications for biodiesel quality. Excessive glycerol can reduce the flash point and increase viscosity, negatively affecting combustion efficiency and engine performance (Ofor *et al.*, 2026). The stronger O-H peak in Sample A suggested it is most susceptible to these issues, while Sample B's weaker O-H peak indicates better suitable for commercial applications, provided moisture content is treated.

Physicochemical Results for Biodiesel Samples

Table 2a and 2b showed each of the samples results of the physicochemical parameter analyses such as viscosity, acid value and density. Viscosity of ASTM biodiesel specification has shown that all the samples where at range of specified standard. While for EN 14214 only sample B was within the permissible range. The acid value (MgKOH/g) and Density of physicochemical shown in all the samples were within the permissible limit of both ASTM and EN standard. However, flash point and moisture content were far higher than the ASTM and EN

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue V May 2026

standard. Many setbacks could attribute to the factors that influence the higher rate such as the temperature, impurities and method of analysis etc.

CONCLUSION

Fourier Transform Infrared (FTIR) Spectroscopy Analysis and physicochemical analysis of biodiesel of this researched was successfully produced from blended feedstock of groundnut oil and coconut oil using KOH as catalyst. The FTIR spectra confirm that all three samples successfully underwent transesterification, with consistent ester functional groups across Samples A, B, and C. However, variations in the O-H stretch region highlight differences in purification efficiency, with Sample A showing the highest residual glycerol or moisture, likely due to its 80:20 feedstock ratio. Sample B's weaker O-H peak suggests better purification, making it a promising candidate for high-quality biodiesel production. These findings had important significant on feedstock ratios and purification processes to minimize byproducts, ensuring compliance with ASTM standards and enhancing fuel performance. Furthermore, vigorously washing and drying protocols is recommended, particularly for Samples A and C, to achieve consistent quality across batches. In physicochemical analysis; viscosity shown a better value with ASTM permissible limit while only sample B fall within permissible of EN standard, the acid value and density were all within the standard limit of ASTM and EN permissible limit. While moisture and Flash point were far higher than both permissible limits. This higher value could be as a result of presence of impurities on the blended feedstock, method of analysis or chemical composition etc. This researched highlight the important of blended feedstock at different ratio to achieved desirable fuel properties. Sample C's indicate the most versatile for aboard applications. The findings indicated that the blended oil biodiesel exhibited improved fuel quality within acceptable biodiesel standards, also vital for FAME of biodiesels production especially in Nigeria where feed stock are very available; also, biodiesel production from these feed-stocks can serve as an alternative renewable and environmentally friendly alternative to fossil diesel (Ofor et al., 2026).

REFERENCE

1. Ofor H.O, Okosun S E, Nweke G.N (2026). GC–MS and Physicochemical of Biodiesel Production from Blended Feedstock Oils Using Potassium Hydroxide as Catalyst, Jordan University of Science & Technology
2. Ofor H.O (2021)," Mechanical Properties, Morphology and Elemental Composition of composites produced from Thermoplastic Polymers Filled with Egg Shell". *International Research Journal of Pure and Applied Chemistry, 22(1), 59-78*
3. Ofor H.O (2021)," Physico-Mechanical Properties of composites Produced from Thermoplastic Polymers Filled with Egg Shell". *Chemical Science International Journal, 28-45.*
4. Ofor H.O (2025). Comparative Study of Thermal Stability in Different Cooking Oil. World News of Natural Science 58, 130 -141.
5. Ofor H.O and Ojiako E.N (2019)," The Effect of Cow Horn as Filler on the Physico-Mechanical Property in Polymeric Matrices Composite". *Journal of Basic Physical Research. 9 (1) 81-90.*
6. Ofor Helen Obianuju, Aiyegbus Opeyemi Praise (2025). Comparative Study of Selected Soil Samples from Industrial Areas of Kogi State**.** International Journal of Biomedical Research Science. Vol 01 No (2)
7. Rahman, K. M., Mashud, M., Roknuzzaman, M., & Al Galib, A. (2010). Biodiesel from jatropha oil as an alternative fuel for diesel engine. International Journal of Mechanical and Mechatronics, 10(3)
8. Rakopoulos, C. D., Antonopoulous, K. A., Rakopoulos, D. C., Hountalas, D. T., & Giakoumis, E. G. (2006). Comparative performance and emissions study of a direct injection diesel engine using blends of diesel fuel with vegetable oils or biodiesels of various origins. National Technical University of Athens, Greece.
9. Saifuddin, N., & Chua, K. H. (2004). Production of ethyl ester (biodiesel) from used frying oil: Optimization of transesterification process using microwave irradiation. Malaysian Journal of Chemistry, 6(1), 77–82. SATRENDS. (2001). ICRISAT crops – groundnut.