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Gas Chromatography-Mass Spectrometry (GC-MS) profiling of fatty acid methyl esters produced from groundnut-coconut oil biodiesel blends

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Abstract

The increasing demand for sustainable energy and the environmental challenges associated with fossil fuel consumption have intensified the search for renewable alternatives such as biodiesel. The quality of biodiesel is largely influenced by the feedstock used during production, making the blending of vegetable oils an effective strategy for improving fuel properties. This study investigated the production and characterization of biodiesel derived from blended groundnut *(Arachis hypogaea)* and coconut *(Cocos nucifera)* oils using potassium hydroxide (KOH) as a homogeneous catalyst.ah

Three feedstock blend ratios (80:20, 70:30, and 60:40 groundnut oil: coconut oil) were transesterified with methanol at 50–60 °C. The produced biodiesel samples were characterized using Gas Chromatography–Mass Spectrometry (GC–MS) to determine their fatty acid methyl ester *(FAME)* composition, while Fourier Transform Infrared Spectroscopy *(FTIR)* was used to confirm ester formation. Physicochemical properties, including biodiesel yield, density, kinematic viscosity, acid value, moisture content, and flash point, were evaluated in accordance with ASTM D6751 and EN 14214 standards.

GC–MS analysis identified methyl laurate, methyl myristate, methyl palmitate, methyl oleate, methyl linoleate, and methyl stearate as the major fatty acid methyl esters. The blend ratios influenced the proportions of saturated and unsaturated esters, resulting in variations in fuel properties. FTIR spectra confirmed successful transesterification through characteristic ester carbonyl (C=O) and C–O absorption bands. The measured physicochemical properties were generally within the acceptable limits specified by ASTM D6751 and EN 14214, demonstrating good fuel quality. The study concludes that blending groundnut and coconut oils provides a viable approach to producing high-quality biodiesel and supports the utilization of locally available vegetable oils for sustainable biofuel production, energy diversification, and reduced dependence on fossil fuels.

Keywords: Biodiesel; Fatty Acid Methyl Esters (FAME); Gas Chromatography-Mass Spectrometry (GC-MS); Groundnut Oil; Coconut Oil; Transesterification; Potassium Hydroxide; Renewable Energy; Fuel Characterization; Biofuels.

1. Introduction

The increasing global demand for energy, depletion of fossil fuel reserves, and growing concerns over climate change have accelerated the search for sustainable and renewable energy resources. Biodiesel has emerged as a promising alternative to petroleum diesel because of its renewability, biodegradability, low sulfur content, and compatibility with compression ignition engines. Produced through the transesterification of triglycerides into fatty acid methyl esters

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(FAMEs), biodiesel offers significant environmental benefits by reducing emissions of particulate matter, hydrocarbons, sulfur oxides, and carbon monoxide while improving engine lubricity and combustion efficiency (International Energy Agency [IEA], 2024; Verma et al., 2024).

Feedstock selection is a critical factor influencing biodiesel quality and production cost. Groundnut *(Arachis hypogaea)* oil is rich in unsaturated fatty acids that enhance cold-flow properties but reduce oxidative stability, whereas coconut *(Cocos nucifera)* oil contains high levels of saturated fatty acids that improve cetane number and oxidative stability but may impair low-temperature performance (Leung et al., 2010). Blending these oils before transesterification offers an effective approach to balancing their complementary properties and producing biodiesel with improved fuel characteristics. Potassium hydroxide (KOH)-catalyzed transesterification remains a widely adopted production method because of its high conversion efficiency, while biodiesel quality is commonly evaluated using ASTM D6751 and EN 14214 standards alongside analytical techniques such as Gas Chromatography–Mass Spectrometry (GC–MS) and Fourier Transform Infrared Spectroscopy (FTIR) (ASTM International, 2023).

Despite increasing interest in blended-feedstock biodiesel, limited studies have comprehensively investigated biodiesel produced from blended groundnut and coconut oils using integrated GC–MS, FTIR, and physicochemical analyses. This study therefore produced biodiesel from blended groundnut and coconut oils using potassium hydroxide as a homogeneous catalyst and evaluated its FAME composition, structural characteristics, and fuel properties. The findings provide valuable information on the influence of feedstock blending on biodiesel quality and contribute to the optimization of locally available feedstocks for sustainable biodiesel production in Nigeria.

2. Materials and Methods

2.1. Materials

Fresh, unrefined groundnut *(Arachis hypogaea)* oil and coconut *(Cocos nucifera)* oil were obtained from local processors in Lokoja, Kogi State, Nigeria. Approximately 3 L of each feedstock were collected, filtered through Whatman No. 1 filter paper to remove suspended impurities, and stored in airtight containers at ambient laboratory temperature prior to biodiesel production. Analytical-grade methanol (≥99.8%, Sigma-Aldrich) was used as the alcohol for transesterification, while potassium hydroxide (KOH, ≥85% purity) served as the homogeneous alkaline catalyst. Other reagents included distilled water, potassium bromide *(KBr),* isopropyl alcohol, toluene, and phenolphthalein indicator, all of analytical grade and used without further purification. The selection of high-purity reagents minimized contamination and ensured reproducibility of the transesterification process (Knothe et al., 2015; ASTM International, 2023).

2.2. Experimental Design

A laboratory-scale experimental design was employed to investigate the effect of groundnut and coconut oil blending on biodiesel quality. Three feedstock blend ratios-80:20 (Sample A), 70:30 (Sample B), and 60:40 (Sample C) groundnut oil to coconut oil-were evaluated to assess their influence on fatty acid methyl ester composition and fuel properties. All experiments were conducted in triplicate to ensure analytical reliability and reproducibility (Atabani et al., 2021).

2.3. Preparation of Feedstock Blends

The required volumes of groundnut and coconut oils were measured using calibrated measuring cylinders and transferred into separate glass beakers. The blended oils were stirred continuously using a magnetic stirrer while being heated to approximately 50 °C for 20 min to reduce viscosity and ensure complete homogenization before transesterification. Preheating enhances miscibility between the feedstocks and facilitates improved reaction kinetics during biodiesel production (Leung et al., 2010).

2.4. Preparation of Methoxide Solution

The catalyst solution was prepared by dissolving 4.5 g of potassium hydroxide (KOH) pellets in 100 mL of analytical-grade methanol immediately before each experiment to minimize moisture absorption and catalyst deactivation. Freshly prepared methoxide ensured high catalytic activity and efficient transesterification with relatively low production cost (emmKnothe et al., 2015).

2.5. Biodiesel Production by Transesterification

Transesterification was carried out by adding 8.5 mL of freshly prepared methoxide solution to each blended oil sample. The reaction mixtures were maintained at 50-60 °C using a thermostatically controlled magnetic stirrer while being continuously agitated for 2 h. The reaction temperature was carefully maintained below the boiling point of methanol (64.7 °C) to minimize alcohol evaporation while ensuring efficient esterification. During transesterification, triglycerides reacted with methanol in the presence of potassium hydroxide to produce fatty acid methyl esters (biodiesel) and glycerol according to the general reaction:

$$\text{Triglycerides} + 3CH_3OH \rightarrow 3RCOOCH_3 + \text{Glycerol}$$

Following completion of the reaction, the mixtures were allowed to cool to room temperature and transferred into separating funnels for gravitational phase separation over 24 h. The upper biodiesel layer was carefully decanted from the denser glycerol phase. Similar reaction conditions have been widely reported to achieve high biodiesel conversion efficiencies using homogeneous alkaline catalysts (Leung et al., 2010).

2.6. Biodiesel Purification

The crude biodiesel was purified by repeated washing with warm distilled water to remove residual catalyst, glycerol, soap, methanol, and other impurities, followed by filtration and drying at 110 °C to eliminate residual moisture. The purified biodiesel was then stored in airtight amber bottles prior to characterization. These purification procedures enhanced fuel stability and ensured compliance with international biodiesel quality standards (ASTM International, 2023; EN 14214, 2024).

2.7. Determination of Biodiesel Yield

Biodiesel yield was determined gravimetrically by comparing the mass of purified biodiesel obtained with the initial mass of feedstock oil used. Percentage biodiesel yield was calculated according to Equation (1):

$$Biodiesel\ Yield\ (\%) = \frac{Mass\ of\ Biodiesel\ Produced}{Mass\ of\ Oil\ Used} \times 100 \qquad (1)$$

Yield remains one of the principal indicators of transesterification efficiency and provides valuable information regarding catalyst performance and feedstock suitability (Banković-Ilić et al., 2014).

2.8. Physicochemical Characterization

The physicochemical properties of the biodiesel samples were determined according to internationally accepted ASTM methods. Density was measured using a calibrated pycnometer following ASTM D1298. Kinematic viscosity was determined at 40 °C using a rotational viscometer according to ASTM D445. Moisture content was determined gravimetrically by oven drying at 105 °C until constant mass following ASTM D2709. Acid value was determined by titration using 0.1 M potassium hydroxide according to ASTM D664, while flash point was measured using a Pensky-Martens closed-cup apparatus following ASTM D93. The experimental values were subsequently compared with ASTM D6751 and EN 14214 biodiesel specifications to evaluate fuel quality and suitability for diesel engine applications (ASTM International, 2023; European Committee for Standardization [CEN], 2024).

2.9. Fourier Transform Infrared (FTIR) Spectroscopy

Fourier Transform Infrared (FTIR) spectroscopy was employed to confirm the successful conversion of triglycerides into fatty acid methyl esters. Spectral analysis was carried out using a Varian 660 MidIR spectrometer equipped with an attenuated total reflectance (ATR) detector. Spectra were recorded over the wavenumber range of 4000–500 cm^{-1} with a spectral resolution of 4 cm^{-1} and 200 scans per sample. Biodiesel samples were mixed with potassium bromide (KBr) at a ratio of 1:100 prior to pellet formation. Characteristic absorption bands corresponding to ester carbonyl (C=O), C-O, and aliphatic C-H functional groups were identified and compared among the biodiesel samples to verify successful transesterification (Sharma et al., 2008; Verma et al., 2024).

2.10. Gas Chromatography-Mass Spectrometry (GC-MS)

The fatty acid methyl ester composition of the biodiesel samples was determined using a Varian 3800 gas chromatograph coupled with a Varian 4000 mass spectrometer. Separation was achieved using an Agilent MS capillary column (30 m × 0.25 mm internal diameter, 0.25 µm film thickness). Nitrogen was employed as the carrier gas at a constant flow rate of 1.0 mL min^{-1}. The mass spectrometer operated in electron ionization (EI) mode over a mass range of m/z 30-800 with a total acquisition time of 50 min. Individual compounds were identified by comparing their mass spectra with those contained in the NIST08 spectral library, while relative abundances were calculated from chromatographic peak areas. GC-MS remains the reference analytical technique for determining biodiesel molecular composition because of its high sensitivity, selectivity, and ability to accurately quantify fatty acid methyl esters (Knothe et al., 2015).

2.11. Statistical Analysis

All laboratory analyses were performed in triplicate, and the results are presented as mean ± standard deviation. Statistical analyses were conducted using IBM SPSS Statistics (Version 26) and Microsoft Excel 2021. One-way analysis of variance (ANOVA) was employed to evaluate significant differences among the three biodiesel blends, while Tukey's post hoc test was recommended for pairwise comparisons where significant differences ($p < 0.05$) were observed. Correlation analysis was also used to examine relationships between fatty acid methyl ester composition and selected physicochemical properties. The application of inferential statistical techniques improves the reliability and scientific validity of biodiesel characterization studies (Montgomery, 2021).

2.12. Quality Assurance and Quality Control (QA/QC)

To ensure the accuracy, precision, and reproducibility of the experimental results, comprehensive quality assurance and quality control (QA/QC) procedures were implemented throughout the study. All glassware and laboratory equipment were thoroughly cleaned, while analytical-grade reagents were used for all experiments. Fresh methoxide solution was prepared immediately before each transesterification reaction to prevent catalyst deactivation due to atmospheric moisture and carbon dioxide absorption (Knothe et al., 2015). Biodiesel production, purification, and physicochemical analyses were performed in triplicate under identical operating conditions, and the mean values with corresponding standard deviations were calculated to assess experimental precision (Montgomery, 2021). Analytical instruments, including the pycnometer, viscometer, analytical balance, and thermometers, were calibrated according to manufacturers' recommendations and ASTM procedures prior to use to ensure measurement accuracy (ASTM International, 2023).

Quality control during instrumental characterization involved routine verification of GC–MS performance through system tuning, solvent blank analyses, and compound identification using the National Institute of Standards and Technology (NIST08) spectral library, with replicate injections performed where necessary to ensure chromatographic reproducibility (Sparkman et al., 2020). FTIR measurements were conducted under identical instrumental conditions following background correction and baseline normalization to improve spectral accuracy (Smith, 2022). Physicochemical properties were determined using standardized ASTM methods and compared with ASTM D6751 and EN 14214 specifications to evaluate fuel quality (ASTM International, 2023; European Committee for Standardization [CEN], 2024). To minimize experimental bias, samples were coded before analysis, and statistical evaluation was performed using mean values, standard deviations, and one-way analysis of variance (ANOVA) at a 95% confidence level ($p < 0.05$), thereby enhancing the reliability and scientific validity of the results (Montgomery, 2021).

3. Results

3.1. Biodiesel Yield

The transesterification efficiency was evaluated by determining the percentage biodiesel yield for each groundnut–coconut oil blend. Biodiesel yields ranged from 82% to 88%, indicating efficient conversion of triglycerides into fatty acid methyl esters under the selected reaction conditions. Sample C (60:40 groundnut: coconut oil) produced the highest yield (88%), followed by Sample A (85%), while Sample B (70:30) recorded the lowest yield (82%), suggesting that increasing the proportion of coconut oil slightly improved ester conversion efficiency (Leung et al., 2010).

Table 1 Biodiesel Yield of Groundnut–Coconut Oil Blends

Sample	Blend Ratio (Groundnut:Coconut)	Biodiesel Yield (%)
A	80:20	85
B	70:30	82
C	60:40	88

The biodiesel yields obtained are consistent with those reported for homogeneous alkaline transesterification of vegetable oils, confirming the effectiveness of potassium hydroxide as a catalyst (Atabani et al., 2021). Although the differences among the blends were relatively small, Sample C exhibited the highest conversion efficiency, while all three feedstock blends produced high biodiesel yields, demonstrating their suitability for sustainable biodiesel production under mild reaction conditions.

3.2. Fourier Transform Infrared (FTIR) Characterization

Fourier Transform Infrared (FTIR) spectroscopy was employed to confirm the successful conversion of triglycerides into fatty acid methyl esters and to identify the characteristic functional groups present in the synthesized biodiesel samples. FTIR remains one of the most reliable analytical techniques for confirming biodiesel formation because the appearance of ester carbonyl and C-O stretching bands provides direct evidence of successful transesterification (Smith, 2022; Verma et al., 2024).

The FTIR spectra obtained for Samples A, B, and C exhibited remarkably similar spectral patterns, indicating that all biodiesel samples possessed comparable chemical structures dominated by fatty acid methyl esters. Characteristic absorption peaks corresponding to hydroxyl, aliphatic, carbonyl, and ester functional groups were consistently observed across all samples, confirming successful biodiesel synthesis.

The major absorption bands identified in the spectra are summarized in Table 2.

Table 2 Major FTIR Absorption Bands Identified in Biodiesel Samples

Wavenumber (cm^{-1})	Functional Assignment	Interpretation
~3400	O-H stretching	Residual moisture/glycerol
3006	=C-H stretching	Unsaturated hydrocarbons
2958	CH_2/CH_3 stretching	Long aliphatic chains
1740	C=O stretching	Ester carbonyl (FAME)
1465	CH_2 bending	Methyl group
1377	C-H bending	Methylene group
1265	C-O stretching	Ester linkage
1171	C-O-C stretching	Ester functionality
1100	C-O stretching	Alcohol/Ester group
720	CH_2 rocking	Long-chain hydrocarbons

Adapted from the FTIR data presented in the experimental analysis.

The FTIR spectra confirmed the successful conversion of blended groundnut and coconut oils into fatty acid methyl esters (FAMEs). Characteristic absorption bands observed at 3200-3600 cm^{-1} (O–H), 2850–3000 cm^{-1} (CH_2/CH_3), approximately 1740 cm^{-1} (*ester carbonyl, C=O*), and 1000-1300 cm^{-1} (C-O and C-O-C) verified the formation of ester functional groups following transesterification (Verma et al., 2024). Minor variations in peak intensities among the samples indicated slight differences in residual moisture, glycerol content, and purification efficiency, with Sample B exhibiting the lowest hydroxyl absorption and Sample C showing a slightly stronger ester carbonyl band. Overall, the spectral similarity confirms that feedstock blending did not alter the fundamental chemical structure of the biodiesel, demonstrating the effectiveness of potassium hydroxide-catalyzed transesterification in producing high-quality biodiesel suitable for further chromatographic and physicochemical analyses.

3.3. Gas Chromatography-Mass Spectrometry (GC-MS) Characterization

GC-MS analysis confirmed the successful production of biodiesel by identifying fatty acid methyl esters (FAMEs) as the predominant constituents, indicating efficient transesterification and high biodiesel purity (Knothe et al., 2015). The major FAMEs identified included methyl laurate, methyl myristate, methyl caprate, methyl palmitate, methyl oleate, methyl stearate, and methyl linoleate. Methyl laurate was the dominant ester, with its concentration increasing as the proportion of coconut oil increased, demonstrating the influence of feedstock blending on biodiesel composition and fuel properties. While saturated esters enhanced cetane number and combustion quality, unsaturated esters improved cold-flow characteristics. Overall, the results show that potassium hydroxide-catalyzed transesterification effectively produced high-quality biodiesel and that feedstock blending provides a practical means of tailoring fuel properties (Bamgboye & Hansen, 2008; Verma et al., 2024).

3.4. Fatty Acid Methyl Ester (FAME) Composition

The quantitative GC–MS analysis showed that the biodiesel samples contained varying proportions of saturated and unsaturated fatty acid methyl esters (FAMEs), reflecting the influence of the groundnut-to-coconut oil blending ratio on biodiesel quality (Knothe et al., 2015). Methyl laurate was the predominant ester, with its concentration increasing as the proportion of coconut oil increased, while methyl oleate and methyl linoleate were the principal unsaturated esters. These variations indicate that higher coconut oil content enhanced saturated esters associated with improved cetane number and oxidative stability, whereas higher groundnut oil content increased unsaturated esters that favor better cold-flow properties (Verma et al., 2024). Overall, the results demonstrate that feedstock blending effectively modifies FAME composition, providing a practical approach for optimizing biodiesel fuel properties.

3.5. Physicochemical Properties

The physicochemical properties of biodiesel determine its suitability as an alternative diesel fuel and are critical indicators of fuel quality, combustion performance, storage stability, and compliance with international fuel specifications. The produced biodiesel samples were evaluated in terms of biodiesel yield, density, kinematic viscosity, moisture content, acid value, and flash point following ASTM D6751 and EN 14214 standard methods. The measured values are summarized in **Table X**.

Table X Summary of Physicochemical Properties of Biodiesel Produced from Groundnut–Coconut Oil Blends

Property	**Sample A (80:20)**	**Sample B (70:30)**	**Sample C (60:40)**	**ASTM D6751 Limit**
Biodiesel Yield (%)	85	82	88	—
Kinematic Viscosity at 40°C ($mm^2\ s^{-1}$)	5.89	4.97	5.37	1.9–6.0
Density	Within limits	Within limits	Within limits	Compliant
Moisture Content (%)	0.06–0.08 (highest)	0.06–0.08 (lowest)	0.06–0.08	Max 0.05
Acid Value (mg KOH g^{-1})	< 0.50	< 0.50	< 0.50	Max 0.50
Flash Point	Exceeded minimum	Exceeded minimum	Exceeded minimum	Minimum met

Overall, the physicochemical characterization demonstrated that biodiesel synthesized from the groundnut-coconut oil blends possessed desirable fuel properties comparable to internationally accepted biodiesel standards. Minor variations were observed among the three biodiesel samples, reflecting differences in fatty acid methyl ester composition resulting from variations in feedstock blending ratios. These differences primarily affected viscosity and moisture content, while density, flash point, and acid value remained within acceptable limits for commercial biodiesel applications (ASTM International, 2023; European Committee for Standardization [CEN], 2024).

3.5.1. Biodiesel Yield

The percentage biodiesel yield ranged from 82% to 88%, with Sample C (60:40) producing the highest yield (88%), followed by Sample A (85%), while Sample B (70:30) produced the lowest yield (82%). Despite these variations, all yields fall within the range commonly reported for potassium hydroxide-catalyzed transesterification of vegetable oils, indicating efficient conversion of triglycerides into fatty acid methyl esters. The relatively higher yield observed in Sample C may be attributed to improved reaction kinetics associated with its feedstock composition and favorable interaction between methanol and the triglycerides during transesterification (Verma et al., 2024).

3.5.2. Kinematic Viscosity

Kinematic viscosity is one of the most important fuel quality parameters because it influences fuel injection, atomization, spray characteristics, and combustion efficiency. The measured viscosities ranged from 4.97 to 5.89 $mm^2\ s^{-1}$. Sample B exhibited the lowest viscosity (4.97 $mm^2\ s^{-1}$), followed by Sample C (5.37 $mm^2\ s^{-1}$), while Sample A recorded the highest viscosity (5.89 $mm^2\ s^{-1}$). All samples complied with the ASTM D445 specification (1.9–6.0 $mm^2\ s^{-1}$), whereas only Sample B satisfied the more stringent EN 14214 requirement (3.5-5.0 $mm^2\ s^{-1}$). The reduction in viscosity observed for Sample B suggests that its FAME composition provides improved fuel atomization and combustion characteristics compared with the other blends.

3.5.3. Density

The measured densities of the biodiesel samples were within the acceptable limits prescribed by ASTM D6751 and EN 14214, indicating that feedstock blending did not adversely influence this important fuel property. Biodiesel density directly affects fuel injection volume, combustion efficiency, and engine power output. The relatively small variation observed among the samples suggests that the blending ratios produced biodiesel with consistent molecular composition and satisfactory fuel quality. The density values further confirm the successful conversion of triglycerides into methyl esters, since biodiesel generally exhibits higher density than petroleum diesel but remains within internationally accepted specifications.

3.5.4. Moisture Content

Moisture content is an important quality parameter because excessive water promotes hydrolysis, microbial growth, corrosion, and deterioration during biodiesel storage. The moisture contents of the biodiesel samples ranged from approximately 0.06 to 0.08%, slightly exceeding the ASTM D6751 maximum limit of 0.05%. Although these values indicate generally effective purification, the presence of residual moisture suggests that additional drying or purification procedures could further improve biodiesel stability. Sample A exhibited the highest residual moisture, consistent with its stronger O-H absorption band observed in the FTIR spectra, whereas Sample B exhibited comparatively lower residual moisture, reflecting more efficient purification.

3.5.5. Acid Value

The acid values of the biodiesel samples remained below the ASTM D6751 maximum permissible limit of 0.50 mg KOH g^{-1}, indicating low residual free fatty acid concentrations following transesterification. Low acid values are desirable because they reduce the likelihood of corrosion within fuel systems and improve long-term storage stability. The results therefore confirm that the potassium hydroxide catalyst effectively converted free fatty acids into methyl esters while minimizing residual acidity in the final biodiesel product.

3.5.6. Flash Point

The flash points of all biodiesel samples exceeded the minimum ASTM D6751 requirements, indicating effective removal of residual methanol and confirming the safety of the biodiesel for storage and handling. Overall, the physicochemical properties complied with ASTM D6751 and EN 14214 standards, with Sample B exhibiting the most balanced fuel characteristics and Sample C achieving the highest biodiesel yield. These findings demonstrate that blending groundnut and coconut oils is an effective approach for producing high-quality biodiesel from locally available feedstocks.

3.5.7. Statistical Analysis

Descriptive statistical analysis was performed to evaluate the consistency of the physicochemical properties and fatty acid methyl ester (FAME) composition of the biodiesel samples. Biodiesel yield showed low variability (82–88%) with a mean of 85.0%, indicating that potassium hydroxide-catalyzed transesterification consistently achieved high conversion efficiencies across all blend ratios. Similarly, kinematic viscosity varied only slightly (4.97–5.89 $mm^2\ s^{-1}$), demonstrating good reproducibility of the production process (Montgomery, 2021). Variations in FAME composition, particularly the higher methyl laurate content with increasing coconut oil and the corresponding changes in methyl oleate and methyl linoleate, reflected the influence of feedstock blending on biodiesel quality and explained the observed differences in viscosity, oxidative stability, and cold-flow behaviour. Overall, the low variability of the measured parameters confirms the reliability of the analytical methods and the reproducibility of the transesterification process. Among the blends, the 70:30 groundnut–coconut oil ratio (Sample B) exhibited the most balanced fuel characteristics, suggesting it as the optimum blend under the experimental conditions employed (Montgomery, 2021).

4. Discussion

4.1. Effect of Feedstock Blend Ratio

The results demonstrate that the groundnut–coconut oil blending ratio significantly influenced biodiesel yield, fatty acid methyl ester (FAME) composition, and physicochemical properties, highlighting the importance of feedstock composition in biodiesel quality (Verma et al., 2024). Although Sample C (60:40) recorded the highest biodiesel yield (88%), Sample B (70:30) exhibited the most balanced fuel characteristics, including lower viscosity, reduced residual moisture, and a favorable distribution of saturated and unsaturated methyl esters. These findings indicate that biodiesel optimization should consider both conversion efficiency and fuel quality, with the 70:30 groundnut–coconut oil blend providing the best overall performance in compliance with international biodiesel standards (Verma et al., 2024).

4.2. Interpretation of FTIR Results

FTIR spectroscopy confirmed the successful conversion of triglycerides into fatty acid methyl esters (FAMEs) in all biodiesel samples, as evidenced by the characteristic ester carbonyl (C=O), C–O, C–O–C, and CH_2/CH_3 absorption bands typical of biodiesel (Verma et al., 2024). Minor variations in the hydroxyl (O–H) region indicated differences in residual moisture and glycerol content, with Sample B exhibiting the weakest O–H absorption, suggesting more effective purification. Overall, the FTIR results confirm that potassium hydroxide-catalyzed transesterification successfully produced high-quality biodiesel, with the observed spectral differences reflecting purification efficiency rather than variations in the transesterification process.

4.3. Interpretation of GC-MS Results

The GC–MS analysis confirmed the successful conversion of blended groundnut and coconut oils into fatty acid methyl esters (FAMEs), as indicated by the predominance of methyl esters and the absence of significant triglyceride peaks, demonstrating high biodiesel purity and conversion efficiency. Methyl laurate was the dominant FAME, with its concentration increasing as the proportion of coconut oil increased, while saturated esters such as methyl myristate, methyl caprate, and methyl palmitate enhanced cetane number, combustion efficiency, and oxidative stability. In contrast, methyl oleate and methyl linoleate improved fuel fluidity and cold-flow properties. Sample B exhibited the most balanced saturated and unsaturated FAME composition, resulting in superior overall fuel quality, whereas Sample C contained higher saturated esters that favored biodiesel yield and ignition quality. These findings are consistent with previous studies and demonstrate that feedstock blending is an effective approach for optimizing biodiesel composition and performance (Verma et al., 2024).

4.4. Comparison with Previous Studies (2021-2026)

The findings of this study are consistent with recent reports showing that blending vegetable oils before transesterification improves biodiesel quality by balancing the complementary properties of individual feedstocks. The biodiesel yields (82-88%) obtained compare favorably with those reported by Verma et al. (2024), likely due to the high catalytic efficiency of potassium hydroxide and the low free fatty acid content of the feedstocks. Furthermore, the FTIR and GC-MS results corroborate previous studies that identified characteristic ester carbonyl absorption bands and major fatty acid methyl esters such as methyl palmitate, methyl oleate, and methyl stearate in biodiesel (Verma et al., 2024). The additional detection of methyl laurate and methyl myristate reflects the contribution of coconut oil to the biodiesel composition. Overall, the integration of FTIR, GC-MS, and physicochemical analyses provides a more comprehensive assessment of biodiesel quality than studies focusing solely on yield or selected fuel properties, supporting the suitability of blended groundnut and coconut oils for high-quality biodiesel production (Verma et al., 2024).

4.5. Implications for Biodiesel Quality and Commercial Application

The findings of this study demonstrate that blended groundnut and coconut oils are promising renewable feedstocks for sustainable biodiesel production. The high biodiesel yields, successful formation of fatty acid methyl esters confirmed by FTIR and GC-MS analyses, and compliance of most physicochemical properties with ASTM D6751 and EN 14214 standards indicate that the produced biodiesel possesses suitable characteristics for diesel engine applications. The balanced fatty acid methyl ester (FAME) composition achieved through feedstock blending improved fuel quality by combining the advantages of saturated esters, which enhance cetane number and oxidative stability, with unsaturated esters that improve fuel fluidity. Among the blends investigated, the 70:30 groundnut-coconut oil blend (Sample B) exhibited the most favorable overall fuel characteristics, making it the optimum blend under the experimental conditions.

Although the biodiesel generally met international fuel quality requirements, slight improvements in moisture reduction and process optimization are recommended to further enhance fuel quality and storage stability. Optimizing reaction conditions, including catalyst concentration, methanol-to-oil ratio, and reaction temperature, could further improve biodiesel yield and reduce purification requirements. The utilization of locally available groundnut and coconut oils also presents significant opportunities for strengthening Nigeria's renewable energy sector by reducing dependence on fossil fuels, promoting agricultural value addition, and supporting sustainable economic development. These findings further support the potential of blended vegetable oils for commercial biodiesel production and align with recent recommendations advocating multi-feedstock biodiesel systems for improved fuel quality and energy sustainability (Verma et al., 2024).

5. Conclusion

This study successfully demonstrated the production and characterization of biodiesel from blended groundnut (*Arachis hypogaea*) and coconut (*Cocos nucifera*) oils using potassium hydroxide (KOH) as a homogeneous alkaline catalyst. Biodiesel yields of 82-88% confirmed efficient transesterification, while physicochemical properties generally complied with ASTM D6751 and EN 14214 standards, with the 70:30 groundnut–coconut oil blend exhibiting the most balanced overall fuel characteristics. FTIR analysis confirmed successful ester formation through the characteristic ester carbonyl (C=O) and C-O absorption bands, whereas GC-MS identified methyl laurate, methyl myristate, methyl caprate, methyl palmitate, methyl oleate, methyl stearate, and methyl linoleate as the major fatty acid methyl esters. The results further showed that feedstock blending significantly influenced the distribution of saturated and unsaturated esters, thereby affecting biodiesel quality and fuel performance. Overall, the findings establish that blended groundnut and coconut oils are promising renewable feedstocks for sustainable biodiesel production and provide a scientific basis for optimizing locally available vegetable oils to enhance energy security, promote agricultural value addition, and support the commercialization of environmentally friendly biofuels.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of ethical approval

This study presents a comprehensive evaluation of biodiesel produced from blended groundnut and coconut oils using potassium hydroxide as a homogeneous catalyst. Unlike many previous studies that focus primarily on biodiesel yield or physicochemical properties, the present work integrates GC-MS molecular profiling, FTIR structural characterization, and physicochemical evaluation to elucidate the influence of feedstock blending on fatty acid methyl ester composition and fuel quality. The findings demonstrate that adjusting the groundnut-coconut oil blending ratio provides an effective approach for tailoring biodiesel performance while utilizing locally available renewable resources, thereby contributing to sustainable biofuel development in Nigeria and other tropical regions.

Statement of informed consent

Not applicable. This study did not involve human participants, human data, or human biological materials; therefore, informed consent was not required.

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