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Production of Biofuel as an Alternative Future Fuel from Bigpod Sesbania using Magnetics Sand/ Mgo Catalyst

Bukar Wakil, Jibrin Sabo Suleiman, and Jibrin Alhaji Audu

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1. Department of Chemistry, Faculty of Science Federal University, Gashua, Yobe State, Nigeria

**Corresponding Author:*
Bukar Wakil
Bukarwakil87@gmail.com

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Abstract

Biofuel is a renewable, green alternative fuel that can be manufactured from vegetable oils, animal fats, or recycled greases. Fourier-transform infrared (FTIR) spectroscopy is a crucial analytical technique for identifying functional groups in biodiesel, confirming its composition and quality. Figure 1 shows the FTIR spectrum of biodiesel derived from Bigpod Sesbania using magnetic sand and MgO as heterogeneous catalysts which reveals characteristic peaks corresponding to key molecular structures. The HPLC-MS analysis of biodiesel produced from Bigpod Sesbania revealed the presence of several key fatty acid methyl esters (FAMEs), hydrocarbons, and alcohols. The primary methyl esters identified, such as methyl palmitate, methyl stearate, and methyl oleate, are well-known biodiesel components, confirming the successful transesterification of Bigpod Sesbania oil into biodiesel. The Physicochemical analysis of the Sesbania herbacea seed oil revealed that ash content of 2.2, specific gravity of 1.1, moisture content of 6.2, Acid value of 5.2, free fatty acid, 3.2 viscosity of 37 and pH value of 6, the XRD spectrum of MgO have the main peaks 2θ= 28º that the powder is crystalline and their crystalline was shown at 2θ = 30.3º, 30.6º, 40º, 50º,47º, 49º and 59º their diffraction peaks was shown at 2θ= 41º presented. The results of magnesium oxide catalyzed Sesbania herbacea methyl ester, magnetic sand catalyzed Sesbania herbacea Methyl ester of biodiesel quality parameters Table 4.2 shows the physical characteristic of biodiesels about to a known standard. From the table, the pour points 2, 2, and cloud point 6,5 and flash points 130,132, viscosity 5.2, 4.6 and pH values 6.3, 6.72.

Keywords: MgO, Magnetic Sand, *Bigpod sesbania*

Introduction

The primary sources of energy that power our civilization are these fossil fuels. The International Energy Agency has forecasted that the world's total energy requirements will rise by half in the next 25 years. On the other hand, global oil product demand has been revised to 84.3 million barrels a day (mb/d) in 2006 and 85.8 mb/d in 2007. Therefore, the continued use of petroleum-sourced fuels is now widely recognized as unsustainable because of depleting supplies and increasing demand. Oil prices have been rising steadily over the past 3 years and surged to a record high above $60 a barrel in June 2005, sustaining a rally built on strong demand for gasoline and diesel and on concerns about refiners' ability to keep up. Fossil fuels are also considered the main source of local environmental pollution. Biofuel is defined by American Society for Testing and Materials (ASTM) International as a fuel composed of monoalkyl esters of long-chain fatty acids derived from renewable vegetable oils or animal fats meeting the requirements of ASTM D6751 (ASTM, 2008). Biofuel is a renewable, green alternative fuel that can be manufactured from vegetable oils, animal fats, or recycled greases. With the increase of petroleum prices and the environmental concerns about pollution, it has become the most potential biofuel because of many advantages such as its environmental friendliness and its better efficiency than fossil fuel (Demirbas, 2007).

Biodiesel has attracted considerable interest as an alternative fuel or extender for petrodiesel for combustion in compression–ignition (diesel) engines. Biodiesel is miscible with petrodiesel in any proportion and possesses several technical advantages over ultra-low sulphur diesel fuel (ULSD, <15 ppm S), such as inherent lubricity, low toxicity, derivation from a renewable and domestic feed- stock, superior flash point and biodegradability, negligible sulphur content and lower overall exhaust emissions. Important disadvantages of biodiesel include high feedstock cost, inferior storage and oxidative stability, lower volumetric energy content, inferior low-temperature operability versus petrodiesel and in some cases, higher NOx exhaust emissions (Knothe, 2008). Many countries throughout the world are trying hard to expand the utilization field of biodiesel in their industrial development. Currently, more than 95% of commercial productions of biodiesel are from edible oils such as soybean oil, rapeseed oil and palm oil, which can be easily obtained on a large scale from the agricultural industry (Gui *et al*., 2008). Biodiesel was produced through esterification and transesterification reactions of vegetable oil and animal fats with an alcohol, Methanol or ethanol is usually the alcohol for biodiesel preparation. The reaction is facilitated with a suitable catalyst either homogeneous or heterogeneous. The amount of free fatty acid is important to select the appropriate catalyst (Helwani *et al*., 2009). Today biodiesel compared with petroleum is considered an environmentally friendly fuel due to its low carbon dioxide emissions, biodegradable fuel, high cetane number, high combustion efficiency, lower aromatic and sulphur content in comparison to petroleum diesel, making biodiesel a competitive fuel in the market (Gemma *et al*., 2004). Biodiesel production aims to get good qualities and quantities by choosing suitable and cheap feedstock such as virgin vegetable oils, used cook oils and animal fats. In this study, *Bigpod sesbania* oil is used for biodiesel production. Other types of edible vegetable oil can be used, for instance; soybean oil, sunflower, palm oil, canola and peanut oil, or even non-edible oils such as sea mango, jatropha, rubber seed and *Pongamia pinnata* (Gui *et al*., 2008). In the present paper, the most matured and wildly-used method in biodiesel production is adopted i.e. using a heterogeneous basic catalyst. Four instrumental analyses are carried out to analyze the catalyst, the biodiesel products and seed oils in detail. In recent years, biodiesel has gained international attention as a source of alternative fuel due to characteristics like high degradability, no toxicity, low emission of carbon monoxide, particulate matter and unburned hydrocarbons (Al-Zuhair, 2007).

Plant profiles

Bigpod sesbania flowers from March to October in Arizona (Evans and Rotar, 1987) or approximately 45–50 days after seeding (ASI, 2013). It is rapidly growing, quick to set seed, and continues to produce seed over a long period. Plants are self-compatible, and seed size and number of fruits are the same for self and out-crossed reproduction (Marshall et al., 2005). The seedpods will remain on the plant throughout winter but they shatter easily after maturity, making machine harvesting difficult (Evans and Rotar, 1987). The seed coat is impermeable. Approximately one-third of the seeds produced are hard seeds (McWhorter and Anderson, 1979) and may not germinate consistently at time of planting. These seeds may grow later with subsequent crops, becoming difficult to manage. (Evans and Rotar 1987). This plant thrives in highly disturbed habitats, sandy sites, shallow flooded areas, and cultivated fields (Sheahan, 2013). Ethiopia is an agriculture-based country where the majority of the population engages in subsistence-level crop and livestock production (Nigussie, 2012), It grows extremely well in the alluvial clay soils of the lower Mississippi River Valley. *Sesbania herbacea* is a fast-growing nodulating legume that can produce 100–146 $kg \cdot ha^{-1}N$ in above-the-ground biomass (Summer, 2010). It is a prolific seed producer yielding up to 21,000 seeds per plant. Cover crop/green manure*: Bigpod sesbania* is grown mainly for use as a soil-improving crop. It can produce 2 to 3 tons/acre in 75 days and 90–130 lbs/acre N in above-ground biomass (Wang and Nolte, 2010). It was once used extensively as a cover crop in citrus groves and by cotton and truck crop growers in California. In Sinaloa Mexico, *Bigpod sesbania* was found to have a higher yield, require less weed cultivation, and was less susceptible to pests than cowpea (*Vigna unguiculata*). *Bigpod sesbania* tends to sprawl and can be supported with sorghum-sudangrass when grown in a warm-season mixture. Growing *Bigpod sesbania* onto a support were helped the plant increase height, thereby optimizing plant leaf position and improving photosynthesis (Baligar et al., 2006). The authentic product or by-product served by *S. sesban* to human beings is not limited to this, it includes its medicinal role in curing diseases and relieving physical suffering. Therefore, promoting *S. sesban* in Ethiopia, where more than 80% of the people are dependent on plants for their health services.

Transesterification reaction

Nowadays, there are four known methods to reduce the high viscosity of vegetable oils to enable their use in conventional compression ignition engines: blending with diesel, pyrolysis, emulsification and transesterification. The pyrolysis and the emulsification however, produce heavy carbon deposits, incomplete combustion, an increase in lubricating oil viscosity and undesirable side products such as alkanes, alkenes, alkadienes, aromatic compounds and carboxylic acids. Regarding the direct use of vegetable oils as fuel for combustion engines, this requires the engines to be modified (Demirbas, 2005). Also, the direct use of vegetable oils is not feasible due to their high viscosity and low volatility which affect the atomization and spray pattern of fuel, leading to incomplete combustion, severe carbon deposits, injector choking and piston ring sticking (Xie and Li, 2006). Thus, the most common way to produce biodiesel is by transesterification of triglycerides of refined/edible types of oils using alcohol, in the presence of an acid or a basic catalyst (López *et al*., 2005). Among the alcohols that have been used to produce biodiesel, either homogeneously or heterogeneously, are methanol, ethanol, propanol, isopropanol, butanol, pentanol and amyl alcohol (Meneghetti *et al*., 2006). The transesterification reaction produces two liquid phases: alkyl esters and crude glycerol (the heavier liquid) as shown in the equation below

Material and Methods

The studies were conducted in Gashea Yobe State, Nigeria,

Sample collection and preparation

Dried and mature *Sesbania herbacea* seeds were obtained from a Gashua market. Two [2kg] of *Sesbania herbacea* seed oil was used, and the seeds were removed. The oil seeds were roasted at 100ºC for about 20 minutes before being ground to tiny coarse particle sizes and sieved before oil extraction. Oil was extracted from the seeds using the Soxhlet extraction method. Extraction of Oil from *Sesbania bispinosa* Seeds, Seeds of *Sesbania bispinosa* will be taken, cleaned and crushed by using an electric mixer of high rpm. Oil will then be extracted with the help of conventional soxhlet apparatus by using n-Hexane as a solvent. Extract oil will then filter and store. The yield is determined by calculating the percentage yield on a dry matter basis. The alkanol used in the transesterification reaction was chosen solely for economic reasons. As a result, methanol was employed in this study. Magnesium oxide and magnetic sand were utilized as catalysts in the reaction because they were effective and available.

Transesterification procedure

The transesterification reaction of WCO was carried out with various catalyst loading, A 6:1 molar ratio of methanol to oil methylation process, was carried out at temperatures 60^{o}C and a reaction time of 60 Minutes. Before starting the transesterification reaction, the oil was heated to 70 °C then cooled to the reaction temperature between 50 – 60 °C. The specified amount of oil, methanol and catalyst were carefully measured and poured in a 250 mL three-neck round-bottom flask equipped with a magnetic stirrer at 400 rpm and a water-cooled condenser. The reaction was allowed to proceed for a specified reaction time (1 – 2 h). The reaction mixture was cooled to 25 °C. After cooling, the mixture was centrifuged at 3000 rpm for 10 min and the catalyst was filtered using a vacuum filter. The liquid was left in a separating funnel for 3 h for separation. The glycerol layer was discharged, and the excess methanol was washed from the biodiesel layer five times using warm distilled water (80 – 100°C). It involved the use of heterogenous base catalysts MgO and Magnetic sand. The percentage yield be calculated using an equation (Mallesham *et al*., 2020)

$$\text{Yield of biodiesel } (\%) = \frac{\text{weight of biodiesel}}{\text{weight of oil}} \times 100 \ldots\ldots\ldots\ldots 1$$

The Physicochemical analysis of the *Sesbania herbacea* seed oil revealed that ash content of 2.2, a specific gravity of 1.1, moisture content of 6.2, acid value of 5.2, free fatty acid, of 3.2 viscosity of 37 and pH value of 6, presented in Table 1.

Figure 1: The Laboratory preparation of the Biofuel.

Table 1: Biodiesel production from used *Sesbania herbacea* oil

Sr. No.	Parameters	Optimum value
1	Amount of used *Sesbania h* oil	100 g
2	Reaction time	60 minutes
3	Oil to methanol ratio	6:1
4	Magnesium oxide	1.0 g wt%
5	Temperature	60^{o}c

Table 2: Analysis of the *Sesbania herbacea* seed oil

Property	Virgin oil
Ash content	2.2
Gravity	1.1
Moisture content	6.0
Acid value	5.2
Free fatty acid	3.2
Viscosity	37
pH value	6.2

Table 3: Energy dispersive X-ray of MgO

	Element Name	Atomic Conc.	Weight Conc.
1	Calcium	2.01	3.59
2	Potassium	2.08	3.09
3	Sulfur	2.04	2.41
4	Chlorine	2.08	2.19
5	Titanium	1.10	2.15
6	Phosphorus	2.05	2.39
7	Silicon	2.14	2.90
8	Aluminium	1.40	1.55
9	Oxygen	2.01	1.10
10	Carbon	37.0	17.0
11	Iodine	2.02	8.08
12	Silver	1.70	6.70
13	Zinc	2.01	6.01
14	Nitrogen	2.05	1.00
15	Sodium	0.67	0.63
16	Iron	0.00	0.00

The XRD spectrum of MgO

Figure 4 the XRD spectrum of MgO has the main peaks 2θ= 28º that the powder is crystalline and their crystalline was shown at 2θ = 30.3º, 30.6º, 40º, 50º,47º, 49º and 59º their diffraction peaks was shown at 2θ=41º was presented (Ali et al., 2021)

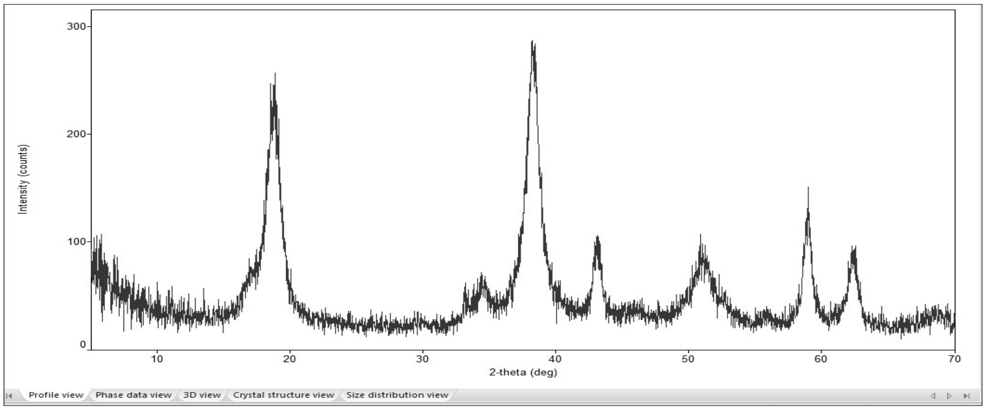

Figure 4: XRD spectrum of MgO

Energy dispersive X-ray of catalyst sample (MgO)

Energy dispersive X-ray of catalyst sample (MgO) obtained Table 3: magnesium has higher atomic and weight concentrations of 42.0 and 41.60 (Aliyu et al., 2021). while titanium has the least value as shown in Table 2: Results revealed high atomic concentration of Ca (2.01%), O (2.01%), S (2.04%), N (2.05%), K (2.08%), Si (2.14%), P (2.05%) Cl (2.08%), I (2.02%), Ag (1.70%), and Na (1.07%) Mg (42.0 %), followed by C (37.0%), Zn (2.01%).

Magnesium oxide catalyzed *Sesbania herbacea* methyl ester.

Magnesium oxide catalyzed *Sesbania herbacea* methyl ester, magnetic sand catalyzed *Sesbania herbacea* Methyl ester of biodiesel quality parameters Table 4. shows the physical characteristics of the biodiesels about known standard (Yelwae et al., 2017). From the table, it can be seen that the pour point 2, 2, cloud point 6,5 flash point 130,132, viscosity 5.2, 4.6 and pH values 6.3,6.72.

Table 4: Biodiesel parameters

Fuel Property	**MgCBSME**	**MSCBSME**	Limit (ASTMD6751)	**Specification** **US**	**UK**
Viscosity (cst)	5.2	4.6	1.9–6.0	1.9-6.0	3.5-5.0
Flash point (◦C)	130	132	130 min.	315-350	360
Cloud (◦C)	6	5	-3 – 12	-3-12	-
Pour	2	2	-3 – 16	-15-10	-

point (◦C)					
pH value	6.3	6.2	------	9	9

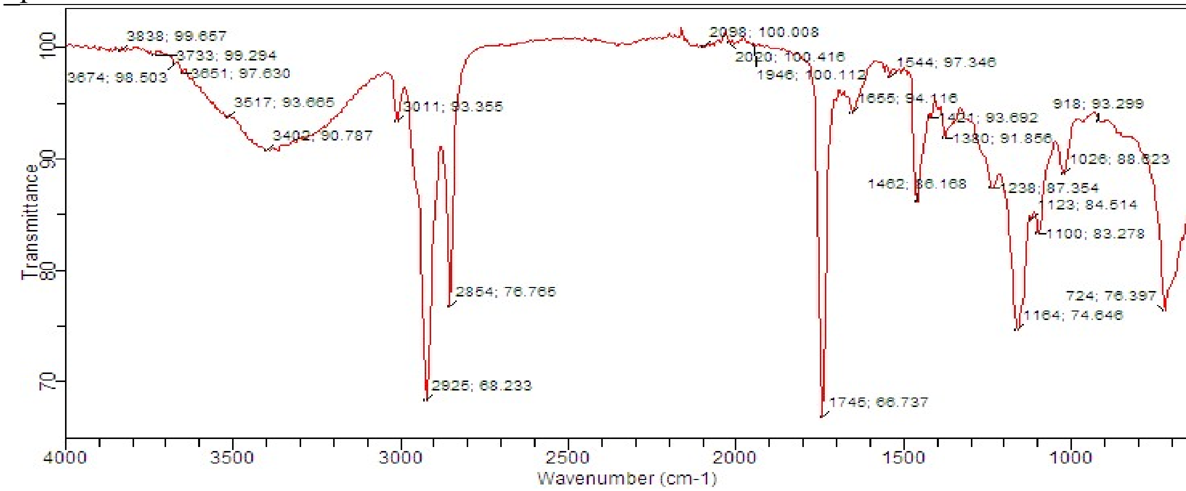

Figure 5. FTIR Spectrum of Biodiesel from Bigpod Sesbania

Fourier-transform infrared (FTIR) spectroscopy is a crucial analytical technique for identifying functional groups in biodiesel, confirming its composition and quality. Figure 1 shows the FTIR spectrum of biodiesel derived from *Bigpod Sesbania* using magnetic sand and MgO as heterogeneous catalysts which reveals characteristic peaks corresponding to key molecular structures. The presence of a broad O-H stretching band at 3401 cm⁻¹ indicates minor moisture content or residual alcohol (Enders et al., 2021), while the C-H stretching vibrations at 3011 cm⁻¹ confirm unsaturated fatty acids (Verma et al., 2024). The peaks at 2925 and 2854 cm⁻¹ correspond to the asymmetric and symmetric stretching of methylene (-CH2) groups, which are typical of long-chain hydrocarbon structures in biodiesel (Mulula et al., 2022). The most significant peak at 1745 cm⁻¹ is attributed to the ester carbonyl (C=O) stretching, confirming the successful transesterification of triglycerides into fatty acid methyl esters (FAMEs) (Muthubi et al., 2023). Another key peak at 1655 cm⁻¹ suggests the presence of C=C stretching from unsaturated fatty acids (Huamán et al., 2023), while the bands at 1462 cm⁻¹ and 1380 cm⁻¹ indicate CH2 and CH3 bending vibrations, respectively. The C-O stretching vibrations at 1238 cm⁻¹, along with additional peaks at 1164, 1100, and 1028 cm⁻¹, further reinforce the presence of esters, affirming the conversion of oil feedstock into biodiesel (Aliyu et al., 2021). A minor peak at 2194 cm⁻¹ suggests the presence of trace alkynes or impurities (Atadashi & Darius, 2021), while the peak at 724 cm⁻¹ corresponds to out-of-plane bending vibrations in long-chain hydrocarbons or aromatic compounds. These observations, in conjunction with literature-reported biodiesel spectra, confirm that the obtained biodiesel meets structural expectations for alternative fuel sources. Overall, the FTIR spectrum validates the efficiency of the applied catalytic process in producing biodiesel with a composition suitable for sustainable energy applications.

Table 5: Identified Compounds in Biodiesel Using HPLC-MS

Peak	Identified Compound	Molecular Formula	Molecular Mass (g/mol)	Retention Time (RT, min)	Relative Abundance (Area %)
1	Phytol	$C_{20}H_{40}O$	270	3.5	2.5
2	Methyl tetradecanoate	$C_{15}H_{30}O_2$	242	4.5	1.26
3	1-Decanol, 2-hexyl-	$C_{16}H_{34}O$	242	5.2	5.51
4	2-Tetradecanol	$C_{14}H_{30}O$	214	6.4	4.52
5	Methyl palmitate (Hexadecanoic acid, methyl ester)	$C_{17}H_{34}O_2$	270	7.1	97.08
6	1-Nonadecene	$C_{19}H_{38}$	266	8.3	5.11
7	9-Octadecenoic acid (Z)-, methyl ester (Methyl Oleate)	$C_{19}H_{36}O_2$	296	11.3	100
8	Methyl stearate	$C_{19}H_{38}O_2$	298	12.0	8.94
9	1-Docosene	$C_{22}H_{44}$	310	14.4	3.25
10	Nonadecane	$C_{19}H_{40}$	268	14.6	2.27
11	Tetradecanoic acid, 10,13-dimethyl-, methyl ester	$C_{17}H_{34}O_2$	270	19.7	1.13
12	1-Eicosanol	$C_{20}H_{42}O$	298	21.3	3.3
13	Tetracosane	$C_{24}H_{50}$	338	21.5	1.45
14	Diisooctyl phthalate	$C_{24}H_{38}O_4$	390	26.3	2.34
15	2-Nonadecanol	$C_{19}H_{40}O$	282	28.1	2.19
16	2-Decanol	$C_{10}H_{22}O$	158	28.2	1.22

Table 5 summarizes the HPLC-MS analysis of biodiesel produced from *Bigpod Sesbania* which revealed the presence of several key fatty acid methyl esters (FAMEs), hydrocarbons, and alcohols. The primary methyl esters identified, such as methyl palmitate, methyl stearate, and methyl oleate, are well-known biodiesel components, confirming the successful transesterification of *Bigpod Sesbania* oil into biodiesel. The presence of long-chain alcohols like 1-eicosanol and 2-nonadecanol, as well as hydrocarbons such as nonadecane and tetracosane, suggests minor impurities or incomplete conversion of free fatty acids. Notably, diisooctyl phthalate was detected, indicating possible contamination from plastic storage or lab materials. The composition aligns with previous studies on biodiesel production from non-edible oils. A review by Kavinprabhu and Moorthi (2023) highlights that methyl esters derived from non-edible plant oils, such as Bigpod Sesbania, exhibit fuel properties that meet biodiesel standards (Kavinprabhu & Moorthi, 2023). The study confirms that key FAMEs, particularly methyl palmitate and methyl oleate, contribute to biodiesel's oxidative stability and combustion efficiency. This aligns with our findings, where methyl palmitate (97.08% area) and methyl oleate (100%

area) were dominant components. Additionally, the high presence of phytol (RT: 3.5 min) in multiple peaks suggests chlorophyll degradation, a phenomenon also observed in biodiesel derived from other plant-based oils. Ali et al. (2021) investigated the impact of phytol in biodiesel production and found that while its presence does not significantly impact fuel performance, it may affect stability over time (Ali et al., 2021). The identification of methyl stearate (8.94%) is another positive indicator, as it contributes to a higher cetane number, which improves ignition quality. Compared to conventional feedstocks, Bigpod Sesbania oil biodiesel demonstrates similar FAME composition to commonly used non-edible oils, such as *Jatropha curcas* and *Pongamia pinnata* (Muthubi et al., 2023). The presence of 1-docosene and tetracosane suggests minor hydrocarbon impurities, potentially from unreacted lipids or thermal degradation during processing. This is a common occurrence in biodiesel from non-edible oils, where additional purification steps are required (Kipkoech & Takase, 2023). In conclusion, the HPLC-MS results confirm that Bigpod Sesbania oil is a viable biodiesel feedstock, producing high-yield FAMEs with fuel properties comparable to other non-edible plant oils. While minor impurities and plastic contamination were detected, further purification can improve fuel quality. This study reinforces the potential of Bigpod *Sesbania* as an alternative biodiesel source, contributing to sustainable energy solutions.

Conclusion

In conclusion, the physicochemical analysis of *Sesbania herbacea* seed oil indicates that it has a variety of notable properties such as an ash content of 2.2, specific gravity of 1.1, moisture content of 6.2, acid value of 5.2, free fatty acid of 3.2, viscosity of 37, and a pH of 6. These characteristics are essential for understanding its potential in biodiesel production. The XRD spectrum of magnesium oxide (MgO) demonstrated the crystalline nature of the powder with distinct diffraction peaks, especially at $2\theta = 28^{o}$, and revealed its role as a catalyst. The energy dispersive X-ray analysis showed that magnesium was the predominant element in the catalyst sample, with significant atomic concentrations of calcium, oxygen, sulfur, nitrogen, and other elements, while titanium had the lowest concentration. The biodiesel produced from *Sesbania herbacea* using magnesium oxide and magnetic sand catalysts exhibited good physical characteristics, with a pour point of 2°C, cloud point of 6.5°C, flash point around 130-132°C, viscosity ranging from 4.6 to 5.2, and a pH value between 6.3 and 6.72. the combination of Fourier-transform infrared (FTIR) spectroscopy and high-performance liquid chromatography-mass spectrometry (HPLC-MS) analysis provides a comprehensive evaluation of biodiesel derived from *Bigpod Sesbania* (Atadashi & Darius, 2021). FTIR analysis confirms the successful transesterification of triglycerides into fatty acid methyl esters (FAMEs) through the identification of characteristic peaks such as the ester carbonyl (C=O) stretching at 1745 cm^{-1} and the unsaturated fatty acid C=C stretching at 1655 cm^{-1}. The spectral data supports the biodiesel's composition, which is consistent with expectations for a sustainable alternative fuel source. HPLC-MS further corroborates these findings, revealing dominant methyl esters such as methyl palmitate and methyl oleate, along with minor impurities, including hydrocarbons and alcohols (Ali et al. 2021). Despite minor contamination such as diisooctyl phthalate, the results suggest that *Bigpod Sesbania* oil is a viable feedstock for biodiesel production, offering fuel properties comparable to other non-edible oils like *Jatropha curcas and*

Pongamia pinnata. Overall, the study highlights *Bigpod Sesbania* as a promising biodiesel source, with minor impurities that can be addressed through additional purification steps. This research contributes to the growing potential of non-edible plant oils in the development of sustainable energy solutions. These results suggest that *Sesbania herbacea* seed oil, with the use of appropriate catalysts, can be a viable source for biodiesel production, meeting the necessary physical and chemical standards for biodiesel quality (Aliyu et al., 2021).

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