

Original Research Article

Synthesis and Physicochemical Characterization of Biodiesel from *Jatropha Curcas* Seed Oil Collected in the Railway Quarters Bauchi

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ABSTRACT

This study investigated the synthesis of biodiesel from *Jatropha curcas* seeds using methanol as an esterification agent. The process commenced with the extraction of oil from the seeds through solvent extraction, followed by a comprehensive analysis of the oil's physicochemical properties to evaluate its suitability for biodiesel production. The extracted oil exhibited favorable properties, including a saponification value of 187.14 mg KOH/g oil NaOH, an acid value of 1.00 mg/L, a peroxide value of 6.600 mg/g, free fatty acid content of 0.990 mg/g, an iodine value of 57.147 mg/g, specific gravity (dimensionless, relative to water at 25 °C) (dimensionless, relative to water at 25 °C) of 0.802, and a density of 0.911 g/cm³. Its liquid state at 25 °C further supports its potential as a viable feedstock. Biodiesel was subsequently synthesized via a catalyzed transesterification reaction and subjected to a quality assessment. The resulting biodiesel displayed a pH of 5.50, a cloud point of 2 °C, a pour point of -2 °C, and a flash point of 147 °C. Additional measured properties include a density of 0.911 g/cm³, specific gravity (dimensionless, relative to water at 25 °C) (dimensionless, relative to water at 25 °C) of 0.802, a saponification value of 187.14 mg KOH/g oil, a peroxide value of 53.1 mg/g NaOH, an acid value of 2.38 mg/L, free fatty acid content of 1.19 mg/g, and an iodine value of 54.247. The close alignment of these values with established biodiesel standards confirms that *Jatropha curcas* seed oil is a suitable and commercially viable raw material for biodiesel production.

Introduction

The rapid growth of the global population has led to a corresponding increase in energy demand, placing immense pressure on existing energy resources worldwide. Energy is essential for virtually all human activities; however, more

than 86% of the world's current energy supply is derived from non-renewable fossil fuels [1,2]. The continued dependence on these diminishing petroleum-based resources results in price instability and exacerbates environmental challenges, including greenhouse gas emissions, climate change, and ozone layer depletion.

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In response to these issues, there has been growing global interest in sustainable and environmentally friendly alternatives to fossil fuels. Among these, biodiesel has emerged as a promising renewable energy source due to its biodegradability, lower emissions profile, and compatibility with existing diesel engines. Biodiesel can be used directly in conventional diesel engines without requiring significant modifications, as its key properties, such as specific gravity (dimensionless, relative to water at 25 °C) (dimensionless, relative to water at 25 °C), cetane number, viscosity, cloud point, and flash point, are comparable to those of petroleum diesel [3,4].

Conventionally, biodiesel is produced via the transesterification of vegetable oils or animal fats using short-chain alcohols. Although edible oils were initially used as primary feedstocks, their impact on food security has prompted a shift toward the exploration of non-edible and waste oils [5]. This transition highlights the need for further research on the environmental implications and biodegradability of biodiesel derived from alternative feedstocks.

In tropical Africa, *Jatropha curcas* has gained attention as a viable non-edible oilseed crop for biodiesel production. Native to Mexico and later introduced to Africa and Asia by Portuguese explorers, *Jatropha curcas* belongs to the Euphorbiaceae family and is noted for its medicinal applications and resilience in arid environments. The plant is well-suited to poor soils and regions with limited rainfall, making it particularly advantageous for smallholder farmers [6]. Additionally, *Jatropha curcas* contributes to land restoration and soil conservation and offers economic potential due to its fast growth rate and early seed production, often within the second year of cultivation. This study aimed to synthesize biodiesel from *Jatropha curcas* seed oil and evaluate its physicochemical properties to assess its viability as a sustainable fuel alternative.

Experimental

Materials

Laboratory Apparatus

The following laboratory apparatus and equipment were used in this study:

- Conical flasks
- Erlenmeyer flasks
- 250 mL volumetric flasks
- Measuring cylinders
- Beakers
- Burettes
- Density bottle
- Separation funnel
- Retort stand
- Mechanical stirrer
- Heating mantle
- Laboratory oven
- Soxhlet extractor
- Mortar and pestle
- Cotton wool
- Digital weighing balance
- Pensky-Martens closed cup tester
- Thermometer

Preparation of Reagents

Wij's Reagent

2 grams of iodine and 6 grams of potassium iodide were dissolved in 100 milliliters of distilled water.

Sodium Thiosulfate Solution (0.1 M)

25 grams of sodium thiosulfate were weighed and dissolved in distilled water then transferred to a 1 dm³ (1,000 mL) volumetric flask and diluted to the mark with distilled water.

Aqueous Potassium Hydroxide Solution (0.5 M)

2.8 grams of potassium hydroxide were dissolved in 40 milliliters of distilled water and then diluted to 100 milliliters using a volumetric flask with additional distilled water.

Ethanolic Potassium Hydroxide Solution (0.5 M)

2.8 grams of potassium hydroxide were dissolved in 40 milliliters of ethanol, and then diluted to 100 milliliters with ethanol using a volumetric flask.

Hydrochloric Acid Solution (0.5 M)

4.180 milliliters of concentrated hydrochloric acid were measured and diluted to 100 milliliters with distilled water in a volumetric flask.

Potassium Iodide Solution (5%)

5 grams of potassium iodide were dissolved in 50 milliliters of distilled water, and then transferred to a 100 milliliter volumetric flask and diluted to volume with distilled water.

Potassium Iodate Solution (30%)

30 grams of potassium iodate were dissolved in 40 milliliters of distilled water, and then diluted to 100 milliliters in a volumetric flask.

Starch Indicator (1%)

1 gram of starch was dissolved in 50 milliliters of distilled water and subsequently diluted to 100 milliliters in a volumetric flask.

Methods

Sample Collection and Preparation

Fresh *Jatropha curcas* fruits were harvested from the Railway Quarters in Bauchi, Nigeria. Taxonomic identification was conducted at the Department of Biological Sciences, Abubakar Tafawa Balewa University, Bauchi. The fruits were sun-dried for two days and manually dehulled to obtain the seeds. The seeds were further dried to minimize moisture content and stored in a clean, dry, and well-ventilated area until oil extraction. **Figure 1** shows collected dried *Jatropha curcas* fruits



Figure 1: Dried *Jatropha curcas* fruits.

Oil Extraction

Approximately 394 g of ground *Jatropha curcas* seeds were subjected to solvent extraction using a Soxhlet extractor and n-hexane as the solvent. The extraction process was continued until about 90% of the oil content was recovered. The crude oil was filtered, and the solvent was removed using a rotary evaporator. Final traces of solvent were eliminated by drying the oil in an

oven at 105 °C. **Figure 2** presents the extracted oil from *Jatropha curcas*.

Biodiesel Production via Transesterification

A sodium methoxide solution was prepared by dissolving 1.00 g of sodium hydroxide (NaOH) in 100 mL of methanol under gentle heating and stirring. Ninety milliliters of the extracted oil were reacted with the methoxide solution and stirred for 2 hours and 15 minutes. The mixture

was then poured into a separating funnel and left to settle overnight. The denser glycerol layer was drained off. The biodiesel layer was washed with warm distilled water to remove residual

impurities until the wash water was clear. The final biodiesel (fatty acid methyl esters, FAMES) was dried and stored for analysis.



Figure 2: Extracted oil from *Jatropha curcas*.

Physico-Chemical Characterization of Biodiesel

Fuel Quality Parameters

i. Pour Point (PP)

To determine the pour point, a representative sample of diesel was cooled in a controlled environment and periodically examined for flowability. At set temperature intervals, the sample container was tilted and held horizontally for 5 s. The lowest temperature at which the sample ceased to flow under gravity was recorded. An increment of 3 °C was added to this temperature to obtain the final pour-point value. This procedure was conducted in accordance with [7-9] to ensure an accurate assessment of the temperature below which the diesel becomes too viscous to flow, thereby providing critical information about its usability in low-temperature conditions.

ii. Cloud Point

Using the same setup, the temperature at which a visible cloud appeared at the bottom of the tube was noted as the cloud point [3].

iii. Flash Point (FP)

The flash point of the diesel was determined according to the [10] using a Pensky-Martens closed cup tester. The sample was heated in a closed-cup apparatus with continuous stirring at a controlled rate. An ignition source was periodically introduced into the vapor space above the sample as the temperature increased to initiate combustion. The flash point was recorded as the lowest temperature at which vapors above the sample ignited.

iv. pH Measurement

A calibrated digital pH meter was used to measure the pH of 10 mL of biodiesel. The pH electrode was cleaned, dried, and immersed in the sample .

Density and Specific Gravity (dimensionless, relative to water at 25 °C) (dimensionless, relative to water at 25 °C) Determination

i. Specific Gravity (dimensionless, relative to water at 25 °C) (dimensionless, relative to water at 25 °C):

A dry, clean specific gravity (dimensionless, relative to water at 25 °C) (dimensionless, relative to water at 25 °C) bottle was weighed, and then filled with distilled water and reweighed. The same procedure was repeated using the biodiesel sample. Specific gravity (dimensionless, relative to water at 25 °C) (dimensionless, relative to water at 25 °C) was calculated using Equation 1.

$$\text{Specific Gravity} = \frac{W_3 - W_1}{W_2 - W_1} \quad (1)$$

ii. Density

The bottle was again dried, filled with biodiesel, and weighed. Density was determined by Equation 2 [8].

$$\text{Density} = \frac{\text{Mass of bottle+biodiesel} - \text{Mass of the empty bottle}}{\text{volume of biodiesel}} \quad (2)$$

Percentage Yield of Oil

The yield of extracted oil was calculated using Equation 3.

$$\text{Percentage Yield} = \left(\frac{\text{Mass of oil extracted}}{\text{initial mass of seed sample}} \right) \times 100 \quad (3)$$

Acid Value Determination

5 g of biodiesel was dissolved in 50 mL of a neutralized ethanol/ether mixture and heated for 10 minutes. After cooling, the solution was titrated with 0.5 M KOH using phenolphthalein. Acid value was calculated using Equation 4.

$$\text{Acid Value} = \frac{TD \times N \times 56.1}{M} \quad (4)$$

Where, TD = Titre Difference = B - S

B = Titre value blank;

S = Titre value with sample

N = Normality of titrating solution (KOH used herein)

M = Mass of sample (g)

Peroxide Value Determination

5 g of sample was dissolved in 30 mL of glacial acetic acid/chloroform and warmed. 0.5 mL potassium iodide was added, followed by 30 mL of

water and 1 mL of starch indicator. The solution was titrated with 0.1 M sodium thiosulfate. Peroxide value was determined by Equation 5.

$$\text{Peroxide Value} = \frac{TD \times N \times 100}{M} \quad (5)$$

Where, TD = Titre Difference = B - S

B = Titre value blank; S = Titre value with sample
N = Normality of titrating solution (KOH used herein)

M = Mass of sample (g)

Saponification Value

2 g of biodiesel were refluxed with 25 mL of ethanolic KOH for 30 minutes. After cooling and adding phenolphthalein, the mixture was titrated with 0.5 M HCl. A saponification value was calculated using Equation 6.

$$\text{Saponification} = \frac{(B-S) \times M \times 56.1}{\text{Sample weight}} \quad (6)$$

Where,

B = Blank titre

S = Sample titre

M = Molarity of HCl

Iodine Value Determination

The iodine value was determined using the method described in [11]. A 2 g sample was dissolved in 20 mL of chloroform and mixed with 25 mL Wijs reagent. The mixture was kept in the dark at 25 °C for 30 min, after which 1 mL of potassium iodide solution and 100 mL of distilled water were added. The mixture was titrated with 0.1 M sodium thiosulfate using starch as indicator. Equation 7 was used to determine the iodine value.

$$\text{Iodine Value} = \frac{TD \times N \times 12.69}{M} \quad (7)$$

Where,

TD = Titre Difference = B - S

B = Titre value blank;

S = Titre value with sample

N = Normality of titrating solution (KOH used herein)

M = Mass of sample (g)

Free Fatty Acid (FFA)

The free fatty acid content was estimated as half the acid value of the biodiesel extract.

Results and Discussion

Physicochemical Properties of Jatropha Seed Oil

Table 1 presents physicochemical properties of Jatropha Seed Oil. Jatropha Seed Oil was a pale yellow, odorless liquid, indicating good quality and stability. The oil had a density of 0.911 g/cm^3 and a specific gravity (dimensionless, relative to water at $25 \text{ }^\circ\text{C}$) (dimensionless, relative to water at $25 \text{ }^\circ\text{C}$) of 0.802. These values

are in consistent with the findings of [12], suggesting that these values are acceptable depending on the specific oil source. The saponification value was 163.81 mg/g KOH , which reflects the average molecular weight of the fatty acids and indicates the oil's potential for a high biodiesel yield. A peroxide value of 53.1 meq/kg suggests moderate oxidation. The acid value of $2.38 \text{ mg KOH/g oil NaOH}$ and the corresponding free fatty acid (FFA) content of 1.19% were within acceptable limits for transesterification without a pretreatment step, as similarly reported by [12,13].

Table 1: Physicochemical properties of Jatropha seed oil

Properties	JS OIL
Colour	Pale Yellow
Odour	odour less
Density (g/cm^3)	0.911
Specific Gravity (dimensionless, relative to water at $25 \text{ }^\circ\text{C}$)	0.802
Saponification value (mg KOH/g oil)	163.81
Peroxide value (meq/kg)	53.1
Acid value (mg KOH/g oil)	2.38
Free fatty acid (FFA) (%)	1.20%
Iodine Value (mg/g)	54.247
Properties	JS OIL
Colour	Pale Yellow
Odour	odour less
Density (g/cm^3)	0.911
Specific Gravity	0.802
Saponification Value (mg/g KOH)	163.81
Peroxide Value (mg/L)	53.1
Acid Value (mg/g NaOH)	2.38
Free fatty acid(FFA)	1.19
Iodine Value (mg/g)	54.247

Additionally, the iodine value of 54.247 mg/g indicates a moderate degree of unsaturation, implying a balance between oxidative stability and cold flow properties. Collectively, these properties confirm that the extracted Jatropha seed oil possesses characteristics that are favourable for biodiesel synthesis.

Physicochemical Properties of Biodiesel and ASTM Standard

Table 2 presents physicochemical properties of biodiesel and ASTM standard. The physicochemical analysis of the synthesized biodiesel revealed that it closely aligned with the ASTM (American Society for Testing Materials) standards in several key areas, supporting its viability as a renewable fuel. The biodiesel was pale brown and odorless, meeting the basic sensory expectations for quality. Its density (0.851 g/cm^3) and specific gravity (dimensionless, relative to water at $25 \text{ }^\circ\text{C}$) (dimensionless, relative to water at $25 \text{ }^\circ\text{C}$) (0.743), although

slightly below the ASTM standard range (0.900–1.000 and 0.880, respectively), still suggest good flow properties and energy content. The saponification value of 191.06 mg KOH/g oil is near the ASTM benchmark of 194.72 mg/g, indicating a favorable average molecular weight of the fatty acids present. Diesel with saponification numbers between 130 and 193 mg/g is considered

suitable for biodiesel production [12]. The acid value of 2.38 mg KOH/g oil NaOH and corresponding free fatty acid (FFA) content of 1.19% are above ASTM biodiesel standards, but still within tolerable limits for transesterification with a pretreatment step. This is in consistent with the findings of [13].

Table 2: Physicochemical properties of biodiesel and ASTM standard

Properties	Biodiesel	ASTM Standard
Colour	Pale Brown	Pale Brown
Odour	Odour less	Odour less
Density (g/cm ³)	0.851	0.900-1.00
Specific Gravity (dimensionless, relative to water at 25 °C)	0.743	0.880
Saponification value (mg KOH/g oil)	191.06	194.72
	2.38	
Peroxide value (meq/kg)	53.1	
Free fatty acid (FFA) (%)	1.20%	0.1-0.2%
Iodine Value (mg/g)	54.247	0.5-1.5

Additionally, the peroxide value of 53.1 meq/kg suggests moderate oxidation, while the iodine value of 54.247 mg/g indicates a moderate degree of unsaturation, balancing the oxidation stability and cold flow properties. Overall, while the biodiesel meets most quality benchmarks, slight deviations in the acid and FFA values indicate the need for refinement steps to fully comply with the ASTM standards.

Fuel Quality Parameters of the Biodiesel Produced and ASTM Standard

Table 2,3 presents fuel quality parameters of the biodiesel produced and ASTM Standard. The fuel

quality parameters of the produced biodiesel, as outlined in the table demonstrated moderate compliance with the ASTM standards. The percentage yield of 26.79% indicates a relatively low conversion efficiency, suggesting room for improvement in the transesterification process or the feedstock preparation. The measured pH of 5.50 falls slightly below the ASTM acceptable range of 5.7–6.2, implying potential residual acidity that could affect long-term storage stability and engine compatibility. The flash point of 147 °C lies well within the ASTM standard range of 100–170 °C, indicating that the biodiesel is relatively safe for handling and storage.

Table 3: Fuel quality parameters of the biodiesel produced and ASTM standard

Fuel Property	Biodiesel	ASTM Standard
% Yield	26.79	-
pH	5.50	5.7-6.2
Flash Point (°C)	147	100-170
Cloud Point (°C)	2	-3-15
Pour Point (°C)	-2	-5-10

Additionally, the cloud point and pour point were measured at 2 °C and -2 °C, respectively, which also fall within the ASTM acceptable limits of -3 to 15 °C (cloud point) and -5 to 10 °C (pour point). These results reflect the reasonable cold flow properties of the biodiesel, making it

potentially suitable for use in moderate climates, although further enhancements could be beneficial for colder environments.

Conclusion

Biodiesel was successfully synthesized from *Jatropha curcas* seed oil collected in the Railway Quarters, Bauchi, using methanol via transesterification. The physicochemical properties of the synthesized biodiesel were evaluated and found to meet the acceptable standards for alternative fuels. The biodiesel had a density of 0.851 g/cm³, kinematic viscosity of 5.10 mm²/s, an acid value of 2.38 mg KOH/g oil, an iodine value of 45.75 gI₂/100 g, flash point of 146 °C, and a pour point of -2 °C. These values fall within the recommended limits, indicating that the produced biodiesel is of good quality and suitable for use in diesel engines. This study demonstrates the potential of *Jatropha curcas* as a sustainable and locally available feedstock for biodiesel production in the Bauchi region.

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