

Measurement of Fuel Properties in Different Blends of Calotropis Root Oil

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Abstract—The depletion of fossil fuel reserves and increasing environmental concerns have accelerated the search for sustainable alternative fuels for diesel engines. Biodiesel derived from non-edible oils has emerged as a promising renewable energy source due to its biodegradability, lower emissions, and compatibility with existing diesel engines. In the present study, biodiesel derived from Calotropis root oil was blended with conventional diesel fuel in different proportions (CB20, CB40, CB60, and CB80) and its physicochemical properties were experimentally investigated according to ASTM standards. Important fuel properties such as density, kinematic viscosity, flash point, fire point, calorific value, cetane number and cloud point were measured using standard laboratory instruments including a hydrometer, Redwood viscometer, Pensky–Marten’s flash point apparatus and digital bomb calorimeter. The results show that density and viscosity increase moderately with increasing biodiesel concentration, while calorific value, flash point and cetane number improve significantly. The Higher biodiesel blends demonstrated improved ignition quality and combustion stability. Among the tested blends, CB60 and CB80 exhibited properties closest to diesel fuel while providing improved safety and thermal stability. These findings indicate that Calotropis root oil biodiesel blends can serve as a potential renewable alternative fuel for diesel engines.

Index Terms—Biodiesel, Calotropis root oil, Alternative fuels, Diesel engine fuel properties, Renewable energy.

I. INTRODUCTION

The continuous increase in global energy demand and the rapid depletion of fossil fuel reserves have created an urgent need for sustainable and renewable energy sources. The Diesel engines are widely used in transportation, agriculture and industrial sectors due to their high efficiency and durability. However, the

excessive dependence on petroleum-based fuels contributes significantly to environmental pollution through emissions of carbon monoxide, nitrogen oxides, hydrocarbons and particulate matter. These concerns have encouraged researchers to investigate renewable fuels that are environmentally friendly and economically viable. Among the available alternatives, biodiesel has emerged as one of the most promising substitutes for conventional diesel fuel due to its biodegradability, renewable nature and compatibility with existing diesel engines [1–3]. The Biodiesel is typically produced from vegetable oils, animal fats or waste cooking oils through the transesterification process that converts triglycerides into fatty acid methyl esters suitable for diesel engine operation [4]. The Biodiesel fuels possess several advantages including higher cetane number, better lubricity, reduced sulfur content and lower emissions compared with petroleum diesel [5,6]. However, biodiesel also exhibits slightly higher viscosity and density, which can influence fuel atomization and injection characteristics. The Blending biodiesel with diesel fuel in different proportions helps maintain desirable fuel properties while utilizing renewable energy content [7,8]. In recent years, considerable research has been directed toward biodiesel derived from non-edible oil sources because they do not compete with food resources and can be cultivated on marginal lands unsuitable for agricultural production [9,10]. Several non-edible feedstocks such as Jatropa, Pongamia, Neem, Mahua and Calotropis have been studied extensively due to their high oil content and adaptability to harsh environmental conditions [11,12]. Among these feedstocks, Calotropis gigantea is considered a promising biodiesel source because it grows abundantly in arid and semi-arid regions and requires minimal agricultural inputs. The oil extracted

from Calotropis roots contains fatty acid components suitable for biodiesel production and can be blended with conventional diesel fuel to improve fuel characteristics [13]. The physicochemical properties of biodiesel play a crucial role in determining its suitability for diesel engine applications. Parameters such as density, viscosity, flash point, calorific value, cetane number, and cold flow characteristics directly affect fuel atomization, combustion efficiency, ignition delay, and overall engine performance [14,15]. Previous studies have reported that biodiesel fuels exhibit higher flash points compared to diesel fuel, improving safety during storage and transportation [16]. Additionally, biodiesel fuels generally possess higher cetane numbers, which lead to shorter ignition delay and smoother engine operation [17]. The Cold flow properties such as cloud point and pour point remain challenges for biodiesel fuels in colder climates. However, blending biodiesel with diesel fuel improves these properties and enhances overall fuel performance [18,19]. Several researchers have investigated biodiesel derived from non-edible oils and reported favorable physicochemical properties and engine performance characteristics. Verma et al. reported that biodiesel blends derived from vegetable oils demonstrate acceptable viscosity and density for diesel engine operation [20]. Patel and Shah observed that biodiesel blends between 20% and 80% provide optimal engine performance with reduced emissions [21]. Rahman et al. demonstrated that higher biodiesel blends improve combustion efficiency and ignition quality in diesel engines [22]. Zhang et al. highlighted recent advancements in biodiesel production technologies and emphasized the importance of evaluating physicochemical properties according to ASTM standards before recommending biodiesel fuels for practical applications [23]. Despite extensive research on biodiesel derived from various vegetable oils, limited studies have focused specifically on biodiesel produced from Calotropis root oil and its fuel properties. Therefore, the present study investigates the physicochemical properties of Calotropis root oil biodiesel blends with diesel fuel and evaluates their suitability as alternative fuels for diesel engines.

II. EXPERIMENTAL METHODOLOGY

A. Preparation of Biodiesel Blends

Calotropis root oil biodiesel was blended with diesel fuel to produce four different blends designated as CB20, CB40, CB60, and CB80. In these blends, the number represents the percentage of biodiesel present in the mixture. CB20 contains 20% biodiesel and 80% diesel, CB40 contains 40% biodiesel and 60% diesel, CB60 contains 60% biodiesel and 40% diesel, and CB80 contains 80% biodiesel and 20% diesel.

B. Density Measurement

Density is an important diesel injection system parameter influencing atomization and fuel spray formation. Density measurements were conducted using a hydrometer according to ASTM D4052 standard as shown in Fig. 1. The density is calculated using the relation $\rho = M/V$, where ρ represents density, M represents mass and V represents volume. Measurements were performed at 20°C.



Figure 1 Hydrometer used for density measurement.

C. Kinematic Viscosity

The kinematic viscosity represents the resistance offered by a fluid to flow and affects fuel pump and injector operation. The viscosity measurements were conducted using a Redwood viscometer according to ASTM D445 standard as shown in Fig. 2.



Figure 2 Redwood viscometer used for viscosity measurement.

D. Flash Point and Fire Point

The flash point is the minimum temperature at which vapors above the fuel ignite when exposed to a test flame. The Fire point represents the temperature at which vapors burn continuously for a few seconds is shown in Fig. 3. The measurements were conducted using the Pensky–Martens closed cup apparatus according to ASTM standards.



Figure 3 Flash point and fire point apparatus.

E. Calorific Value

The calorific value represents the heat released during complete combustion of fuel. The measurements are carried out using a digital bomb calorimeter according to ASTM D5865 standard as shown in Fig. 4.



Figure 4 Digital bomb calorimeter.

III. RESULTS AND DISCUSSION

Table 1 Fuel Properties of Calotropis Biodiesel Blends

Property	CB20	CB40	CB60	CB80	Calotropis Oil	Diesel
Density (kg/m ³)	846	872	880	892	862	860
Viscosity (cSt)	3.38	3.92	3.98	4.17	4.12	5.00
Flash Point (°C)	47	49	53	55	33.5	35
Fire Point (°C)	71	74	75	79	48.23	75
Calorific Value (kJ/kg)	49.5	50.72	52.75	53.7	46.7	45.5
Cetane Number	43	45	46	48	47.8	46
Cloud Point (°C)	-6	-6	-8	-9	5	-7

The density of the biodiesel blends increased gradually with increasing biodiesel concentration as shown in table 1. This increase is attributed to the higher molecular weight and oxygen content of biodiesel compared to diesel fuel. Similarly, kinematic viscosity increased with increasing biodiesel proportion due to the presence of long-chain fatty acid esters in biodiesel. However, the viscosity values remained within acceptable limits for diesel engine operation. Flash point values increased significantly with biodiesel concentration, indicating improved safety during fuel storage and handling. The calorific value increased from CB20 to CB80, indicating higher energy release during combustion. The Cetane number increased with biodiesel content, suggesting improved ignition quality and reduced ignition delay. The Cloud point values decreased slightly with increasing biodiesel concentration, demonstrating improved cold flow characteristics compared with pure Calotropis oil.

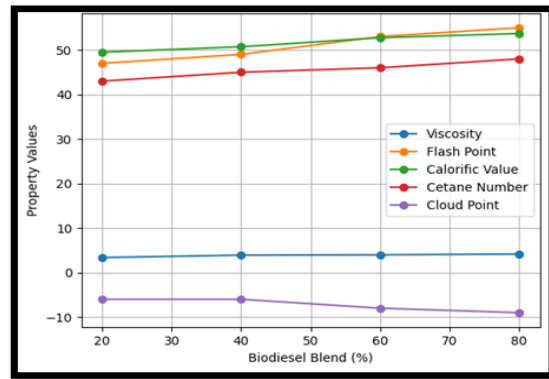


Figure 5 Variation of Fuel Properties against Biodiesel Blend (%)

Figure 5 illustrates the variation of viscosity, flash point, calorific value, cetane number and cloud point with increasing calotropis biodiesel blend ratio (CB20 – CB80). It is observed that viscosity increases from 3.38 to 4.17 cSt (~23.4%), indicating improved lubricity but slightly higher flow resistance, while

flash point rises from 47°C to 55°C (~17%), enhancing fuel safety. The calorific value increases from 49.5 to 53.7 kJ/kg (~8.5%), suggesting better energy output and the cetane number improves from 43 to 48 (~11.6%), indicating superior ignition quality and reduced ignition delay. In contrast, the cloud point decreases from -6°C to -9°C, reflecting improved cold flow properties.

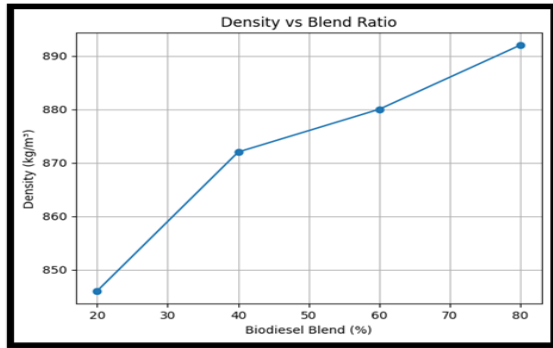


Figure 6 Variation of Fuel Density against Biodiesel Blend (%)

Figure 6 shows the variation of density with increasing calotropis biodiesel blend ratio (CB20–CB80). It is observed that density increases from 846 kg/m³ (CB20) to 892 kg/m³ (CB80), representing an approximate 5.4% increase. This gradual rise is attributed to the higher molecular weight and oxygen content of biodiesel compared to conventional diesel. The increase in density indicates a heavier fuel, which can influence fuel injection and spray characteristics in diesel engines.

IV. COMPARISON WITH OTHER BIODIESEL STUDIES

Table 2 comparison of calotropis biodiesel with other common biodiesel feedstocks

Feedstock	Density (kg/m³)	Viscosity (cSt)	Cetane Number	Reference
Jatropha Biodiesel	880	4.5	51	[1]
Neem Biodiesel	890	4.8	49	[20]
Pongamia Biodiesel	885	4.6	52	[21]
Calotropis Biodiesel	872 – 892	3.9 – 4.17	45 – 48	Present study

The comparison of calotropis biodiesel with other common biodiesel feedstocks, as shown in Table 2, indicates that its fuel properties are within an acceptable and competitive range. The density of calotropis biodiesel (872–892 kg/m³) is comparable to that of jatropha (880 kg/m³), neem (890 kg/m³), and pongamia (885 kg/m³), confirming similar fuel characteristics. The viscosity range (3.9–4.17 cSt) is slightly lower than that of other biodiesels (4.5–4.8 cSt), which is advantageous for better atomization and fuel injection. However, the cetane number (45–48) is marginally lower compared to jatropha (51), neem (49), and pongamia (52), indicating slightly reduced ignition quality. Despite this, the values remain within acceptable limits for diesel engine operation. Overall, calotropis biodiesel demonstrates comparable physicochemical properties and can be considered a viable alternative feedstock for biodiesel production.

V. ERROR ANALYSIS

Experimental uncertainties may arise from instrument limitations and environmental conditions. Density measurements using the hydrometer had an accuracy of ±0.005 g/cm³ with an estimated error of ±1%. Viscosity measurements using the Redwood viscometer had an uncertainty of approximately ±2%. Flash point measurements may vary slightly due to heating rate variations. Calorific value measurements using the bomb calorimeter showed an estimated uncertainty of ±1.5%. To minimize experimental error, each measurement was repeated three times and average values were reported.

VI. CONCLUSIONS

The physicochemical properties of Calotropis root oil biodiesel blends were experimentally investigated according to ASTM standards. The results indicate that biodiesel blends exhibit slightly higher density and viscosity compared to diesel fuel while demonstrating improved flash point, calorific value, and cetane number. Among the tested blends, CB60 and CB80 exhibited fuel properties closest to diesel standards while providing improved ignition quality and thermal stability. These findings indicate that Calotropis root oil biodiesel blends can serve as a promising renewable alternative fuel for diesel engines.

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