



PERFORMANCE CHARACTERIZATION OF BIODIESEL PRODUCED FROM RUBBER SEED OIL AND ITS BLENDS WITH PETROLEUM DIESEL

ABSTRACT

This study evaluates the viability of rubber seed oil (RSO), derived from *Hevea brasiliensis*, as a nonedible feedstock for biodiesel production in Nigeria. Rubber seeds, typically discarded as waste from rubber plantations, were collected, processed, and subjected to oil extraction via the Soxhlet method. Owing to the high free fatty acid (FFA) content of the extracted oil, an acid base transesterification process was employed to produce biodiesel

DIKE CHIJINDU P.¹; OGUNDELE SAMUEL O.²;
SAM OBU C. V.³; & ANIEBONAM CHUKWUKA
A.⁴

¹⁻³Mechanical Engineering Department, Federal Polytechnic Offa. ⁴Science Laboratory Technology Department, Federal Polytechnic Offa.

Corresponding Author: dikeprecious@yahoo.com

DOI: <https://doi.org/10.70382/tijasdr.v10i2.072>

Introduction

The increasing global demand for energy, coupled with environmental concerns over fossil fuel emissions, has driven interest in renewable and eco-friendly alternatives (Atabani *et al.*, 2013). Biodiesel, a mono-alkyl ester derived from vegetable oils or animal fats, has emerged as a promising substitute for petroleum diesel because of its renewability, biodegradability, and lower emissions of harmful pollutants (Issariyakul & Dalai, 2014).

Most commercial biodiesel is currently produced from edible oils such as soybean, palm, and rapeseed. However, reliance on food-grade oils raises serious food-versus-fuel concerns and contributes to rising food prices (Dharma *et al.*, 2016). To address this challenge, researchers have turned to non-edible oil sources. Rubber seed oil (RSO) from *Hevea brasiliensis* is one such promising candidate. Rubber trees are widely cultivated in West Africa, Southeast Asia, and South America primarily for



(B100). The resulting biodiesel and its blends with petroleum diesel (B05, B10, B15, B20) were evaluated for essential fuel properties, including density, kinematic viscosity, calorific value, cetane number, flash point, and pour point. The B100 biodiesel conformed to ASTM D6751 and EN 14214 standards, exhibiting a density of 854 kg/m³, kinematic viscosity of 4.32 mm²/s at 40°C, cetane number of 57, flash point of 148°C, and pour point of 12°C. Relative to petroleum diesel, RSO biodiesel demonstrated a higher cetane number and flash point, alongside a lower pour point, signifying enhanced ignition quality, improved safety in handling and storage, and superior cold-flow performance. The calorific value was slightly lower; the higher density of biodiesel mitigated this in blends, yielding comparable volumetric energy content. The B20 blend achieved an optimal equilibrium between fuel performance, emissions reduction potential, and compatibility with conventional diesel engines. These results affirm RSO as a sustainable, eco-friendly, and economically feasible alternative for biodiesel production, especially in regions with abundant rubber cultivation, thereby promoting waste valorization and energy independence without competing with food resources.

Keywords: Rubber seed oil, Transesterification, Biodiesel, Sustainable, Energy independence.

latex, while the seeds are often discarded despite containing 40–50% oil (Onoji *et al.*, 2016).

With the anticipated increase in natural rubber demand following global sustainability agreements, rubber seed availability is expected to rise significantly, making RSO a strategic feedstock for biodiesel production in rubber growing countries like Nigeria (Banković-Ilić *et al.*, 2012). This study aims to characterize the fuel properties of biodiesel produced from Nigerian rubber seed oil and evaluate its performance when blended with conventional diesel.

Rubber seed oil as a biodiesel feedstock

Numerous studies confirm the high oil yield (35% to 60 %) and favorable fatty acid profile of rubber seeds (Atabani *et al.*, 2013). Rubber seed oil has gained considerable attention as a potential feedstock for biodiesel production due to its abundant availability and high oil content. Rubber seed oil is obtained from the seeds of rubber trees (*Hevea brasiliensis*), which are widely cultivated in regions with significant rubber plantations. The oil content of rubber seeds ranges from 35% to 60%, making it a viable source for biodiesel production. Studies have shown that Rubber seed oil possesses favorable



properties for biodiesel production. It has a high viscosity, which improves lubricity and can potentially reduce wear on engine components. Additionally, rubber seed oil has a low free fatty acid (FFA) content, making it suitable for trans-esterification, the process used to convert vegetable oils into biodiesel. The oxidative stability of Rubber seed oil is also promising, indicating its potential for long-term storage and usage (Onoji *et al.*, 2016).

Challenges and pre-treatment

Raw RSO typically exhibits high free fatty acid (FFA) content (15 to 40 mg KOH/g), necessitating a two-step process: acid esterification to reduce FFA below 1 %, followed by alkaline transesterification (Aransiola *et al.*, 2014; Di Serio *et al.*, 2008). Failure to address high FFA leads to soap formation and drastic yield reduction.

Previous performance studies

Engine tests with RSO biodiesel blends have shown 2 to 8 % lower brake thermal efficiency but significantly reduced CO, HC, and smoke emissions compared to petroleum diesel (Morshed *et al.*, 2011; Omorogbe *et al.*, 2013). Long-term durability studies remain limited, though initial results indicate acceptable wear characteristics due to the inherent lubricity of biodiesel.

Seed collection and oil extraction

Mature rubber seeds were collected from clones of the NIG800 series. Seeds were cleaned, de-husked, and sun-dried for 48 hours, followed by oven drying at 105°C to reduce moisture content below 7%. Kernels were ground and sieved into particle sizes of 0.5mm to 2.5 mm. Oil extraction was performed using a Soxhlet apparatus with n-hexane at 60°C for 6 to 8 hours. The highest oil yield was obtained from 1.0mm to 1.5 mm particles (Onoji *et al.*, 2016).

Biodiesel production

The production of Rubber seed oil biodiesel involves several steps, including oil extraction, pretreatment, and transesterification. The extracted rubber seed oil undergoes a purification process to remove impurities and water content. The purified rubber seed oil is then subjected to esterification and transesterification, a chemical process in which the oil is reacted with an alcohol and a catalyst to produce biodiesel due to high free fatty acid (FFA) content.

Results and discussion

The fuel characteristics of rubber seed oil biodiesel and its blends provide information about combustion and ignition characteristics and overall fuel quality. Analyzing the oil characterization helps understand the performance of biodiesel using rubber seed oil.



Properties of rubber seed oil

Table 1. Physical property of rubber seed and rubber seed oil

Parameter	Composition (wt.%)
<i>Rubber Seed</i>	
Kernel	40.47
Kernel moisture	9.7
Shell	49.83
<i>Rubber Seed Oil</i>	
Carbon residue	0.4
Moisture content	1.73
Ash content	0.001
Volatile matter	97.869

Biodiesel characterization from rubber seed oil

Biodiesel was processed according to criteria established by ASTM, AOAC (1990) and the results are shown in Table 2. Its performance complies with ASTM D 6751 and EN 14214 biodiesel standards. The results show that biodiesel produced from waste rubber seed husks as rubber products and rubber oil as raw material can be used in modern diesel engines.

Table 2. Fuel characteristics of biodiesel produced from rubber seed oil compared to the standard.

Properties	Methods	ASTM Standard	D6751	EN Standard	14214	This study
Density @ 15 °C(kg/m ³)	ASTM D1298	870-900		860-900		854
Water and Sediment (vol%)	ASTM D2709	<0.05		<0.05		0.0062
Acid value (mgKOH/g)	ASTM D664	<0.8		<0.5		0.56
Kinematic viscosity @ 40°C(mm ² /s)	ASTM D445	1.9-6.0		3.5-5.0		4.32
Flash point (°C)	ASTM D93	93 minimum		120 minimum		148
Pour point (°C)	ASTM D97	-15 to 10		0		12
Calorific value (kJ/kg)	ASTM D240					42,500
Cetane number	ASTM D613	47 minimum		51 minimum		57

Characterization of the rubber seed oil biodiesel and its blend with petro-diesel
This section presents experimental data which describes the fuel properties of biodiesel and blends in this study (B00, B05, B10, B15, B20 and B100).

Density

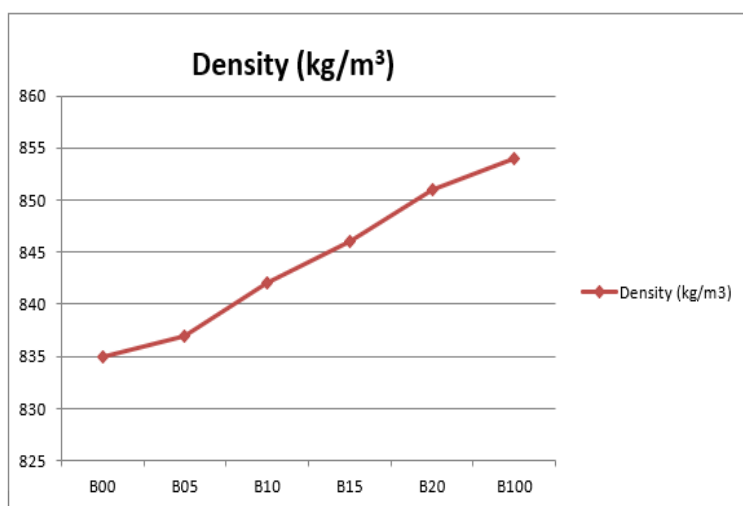


Figure 1. Density of biodiesel blends

Density increased linearly with biodiesel content, from 835 kg/m³ (B00) to 854 kg/m³ (B100). Although slightly higher than petroleum diesel, all blends remained within acceptable limits. Higher density results in greater

mass flow through volume-metered injectors, potentially improving combustion efficiency.

Kinematic viscosity

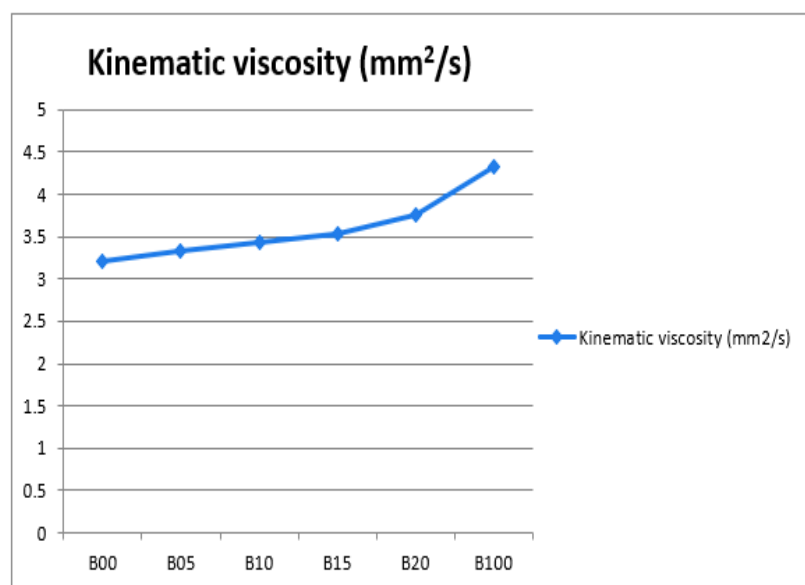


Figure 2. Kinematic viscosity (mm²/s) of biodiesel blends

Viscosity rose from 3.2 mm²/s (B00) to 4.8 mm²/s (B100). While higher than diesel, B100 still complies with both ASTM and EN standards. Proper viscosity ensures good fuel atomization and

lubrication

Calorific value

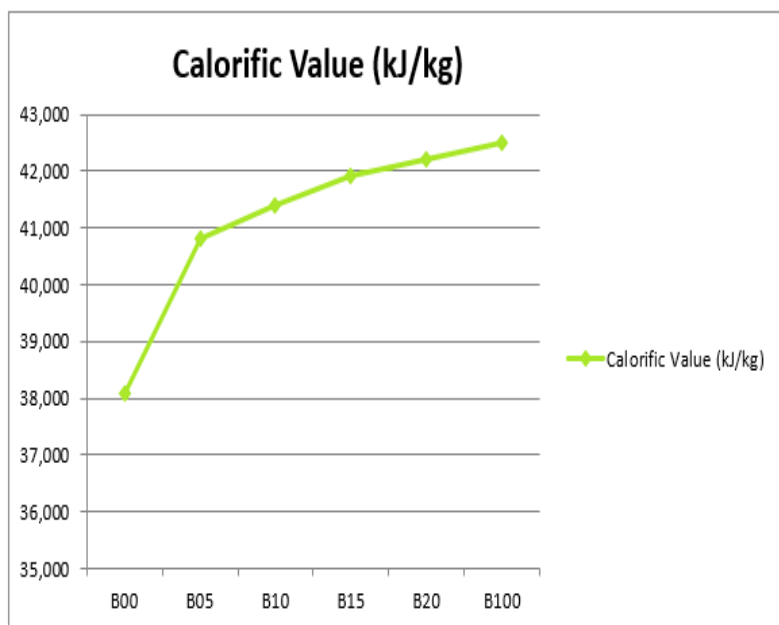


Figure 3. Calorific value of biodiesel blends

The heating value of B100 (42.5 MJ/kg) was approximately 7–8% lower than petroleum diesel (45.8 MJ/kg), which is typical for biodiesels due to oxygen content. However, higher density compensates partially, resulting in

comparable energy delivery per unit volume in blends up to B20.

Cetane number

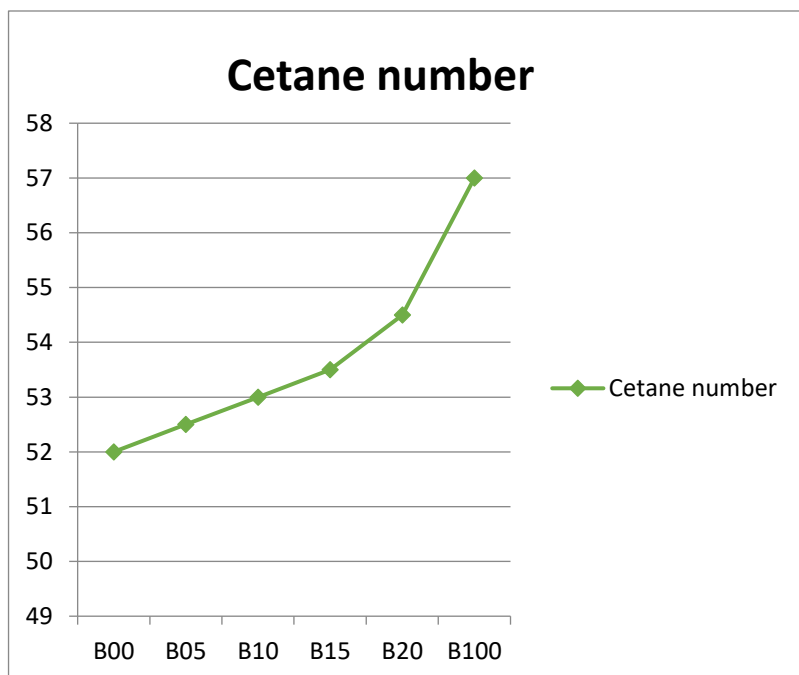


Figure 4. Cetane number of biodiesel blends

B100 recorded a cetane number of 57, significantly higher than petroleum diesel (52). Higher cetane numbers indicate shorter ignition delay, smoother combustion, and reduced emissions.

Flash point

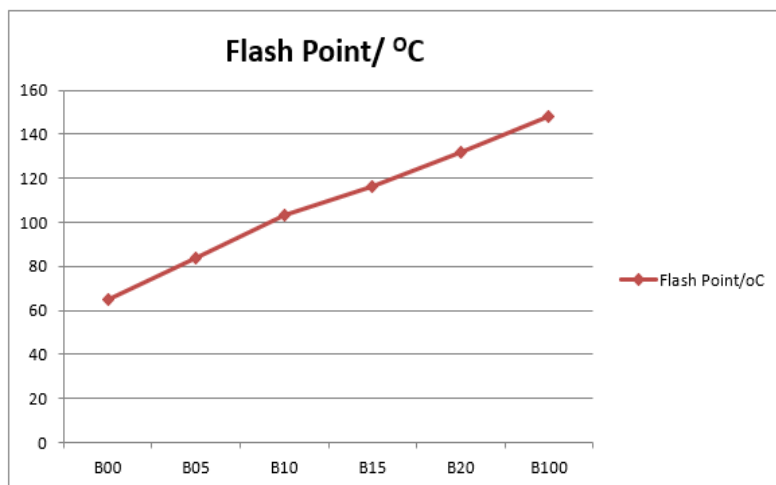


Figure 5. Flash Point of biodiesel blends

The flash point increased dramatically with biodiesel proportion, reaching 148°C for B100 compared to 68°C for diesel. This enhances safety during handling and storage.

Pour point

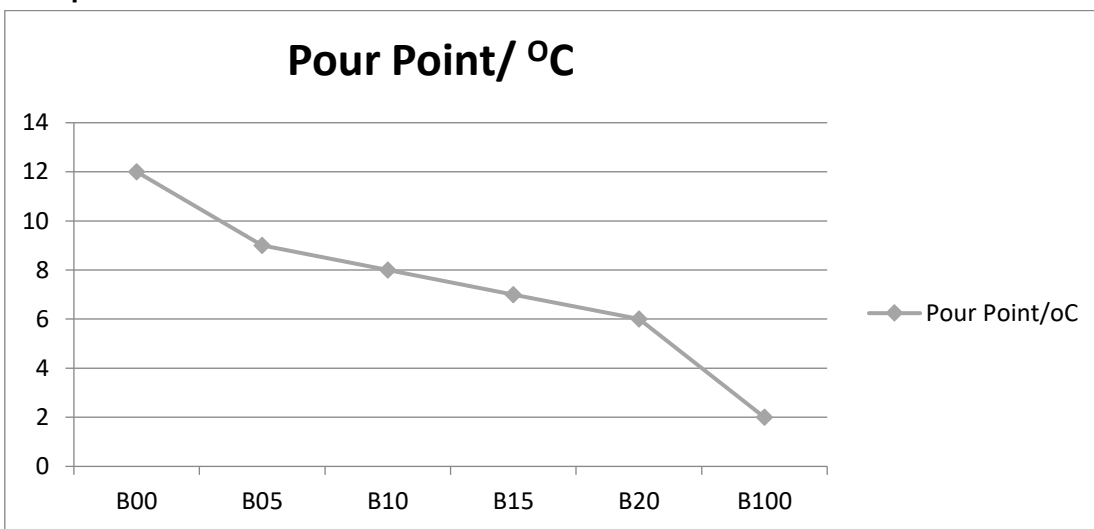


Figure 6. Pour Point of biodiesel blends

B100 exhibited the lowest pour point (2°C), making it suitable for use in cooler climates without additives, unlike petroleum diesel (12°C).

Conclusion

This study demonstrates that biodiesel derived from rubber seed oil (RSO) *Hevea brasiliensis* plantations represents a promising renewable fuel alternative, effectively addressing the dual challenges of energy security and environmental sustainability. The transesterification process successfully mitigated the high free fatty acid (FFA) content of



raw RSO, yielding biodiesel (B100) that fully complies with international standards such as ASTM D6751 and EN 14214. Key fuel properties of B100, including a density of 854 kg/m³, kinematic viscosity of 4.32 mm²/s at 40°C, cetane number of 57, flash point of 148°C, and pour point of 12°C, highlight its superiority in several aspects compared to conventional petroleum diesel (B00). Notably, the elevated cetane number ensures shorter ignition delays and smoother combustion, reducing engine knock and emissions of unburned hydrocarbons (HC), carbon monoxide (CO), and smoke. The substantially higher flash point enhances safety during transportation, storage, and handling, minimizing fire hazards. Blends of RSO biodiesel with petroleum diesel (B05 to B20) exhibited linear trends in properties, with increases in density, viscosity, cetane number, and flash point proportional to biodiesel content. This study confirms that rubber seed oil is a technically viable, environmentally friendly, and economically promising feedstock for biodiesel production and utilizing rubber seeds currently an underused agricultural byproduct for biodiesel production presents a sustainable pathway for energy security in rubber producing nations while reducing waste and avoiding competition with food crops.

References

- AOAC, (1990). *Official Methods of Analysis of the Association of Official Analytical Chemists*, 15th ed. Association of Official Analytical Chemists, Arlington, VA.
- Aransiola, E.F., Ojumu, T.V., Oyekola, O.O., Madzimbamuto, T.F., Ikhu-Omoregbe, D.I.O., (2014). A review of current technology for biodiesel production: State of the art. *Biomass and Bioenergy* 61, 276–297.
- Atabani, A.E., Silitonga, A.S., Ong, H.C., Mahlia, T.M.I., Masjuki, H.H., Badruddin, I.A., Fayaz, H., (2013). Non-edible vegetable oils: A critical evaluation of oil extraction, fatty acid compositions, biodiesel production, characteristics, engine performance and emissions production. *Renewable and Sustainable Energy Reviews* 18, 211–245.
- Banković-Ilić, I.B., Stamenković, O.S., Veljković, V.B., (2012). Biodiesel production from non-edible plant oils. *Renewable and Sustainable Energy Reviews* 16 (6), 3621–3647.
- Dharma, S., Masjuki, H.H., Ong, H.C., Sebayang, A.H., Silitonga, A.S., Kusumo, F., Mahlia, T.M.I., (2016). Optimization of biodiesel production process for mixed *Jatropha curcas*–*Ceiba pentandra* biodiesel using response surface methodology. *Energy Conversion and Management* 115, 178–190.
- Di Serio, M., Tesser, R., Pengmei, L., Santacesaria, E., (2008). Heterogeneous catalysts for biodiesel production. *Energy & Fuels* 22 (1), 207–217.
- Issariyakul, T., Dalai, A.K., (2014). Biodiesel from vegetable oils. *Renewable and Sustainable Energy Reviews* 31, 446–471.
- Morshed, M., Ferdous, K., Khan, M.R., Mazumder, M.S.I., Islam, M.A., Uddin, M.T., (2011). Rubber seed oil as a potential source for biodiesel production in Bangladesh. *Fuel* 90 (11), 3441–3446.
- Omorogbe, S.O., Ikhuoria, E.U., Aigbodion, A.I., Obaze, E.O., Momodu, V.M., (2013). Production of rubber seed oil based biodiesel using different catalysts. *Current Research in Chemistry* 5, 11–18.
- Onoji, S.E., Iyuke, S.E., Igbafe, A.I., Nkazi, D.B., (2016). Rubber seed oil: A potential renewable source of biodiesel for sustainable development in sub-Saharan Africa. *Energy Conversion and Management* 110, 125–134.