6TH International Conference and Workshop on Engineering and Technology Research (ICWETR) LAUFET 2025: 424-435

# Evaluation of the Fuel Characteristics of Biodiesel Produced from Flamboyant (*Delonix regia*) Seed Oil

[1] Owolabi, A. R., [2]Ola, F. A., [1]Manta I.H., [1]Abdulrasak, A.O. and [2]Akande, F. B.

[1]*National Centre for Agricultural Mechanization, Ilorin, Nigeria.*
[2]*Department of Agricultural Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.*

*https://www.laujet.com/*


***Keywords:***

Biodiesel,
Flamboyant seed oil,
Fuel properties,
Renewable energy,
Transesterification,
ASTM standards.

***Corresponding Author:***
*abosede.aremu2022@uniabuja.edu.ng*
*+2348135565615*

**ABSTRACT**

***The increasing global demand for renewable energy sources has driven research into biodiesel production as a sustainable alternative to fossil fuels. This study evaluates the fuel characteristics of biodiesel derived from flamboyant (Delonix regia) seed oil. Oil extraction from flamboyant seed was performed using Soxhlet extraction, followed by transesterification to produce its biodiesel. The physicochemical properties of the extracted oil and the biodiesel were analyzed based on ASTM standards to determine acid value, viscosity, specific gravity, flash point, density and heating value. Results showed that flamboyant seed oil has an acid value of 13.17 mgKOH/g, a specific gravity of 1.05, a viscosity of 5.89 mm²/s, and a flash point of 106°C. The produced biodiesel had a flash point of 120°C, a density of 0.94 g/cm³ and a kinematic viscosity of 1.663 mm²/s, which are comparable to ASTM D6751 biodiesel standards. However, the higher density and lower heating value (0.94 kg/m³ and 15.60 MJ/kg) suggest potential challenges for direct application in internal combustion engines without modification. The study concludes that flamboyant seed oil is a viable biodiesel feedstock, but further pretreatment and optimization of the transesterification conditions are necessary to enhance fuel performance for practical use.***

## INTRODUCTION

Nowadays, there is an urgent need for alternative, cheap and renewable energy resources with no environmental impact, like biodiesel, bioethanol and biogas derived from renewable biomass. Among them, the greatest demand is currently observed for biodiesel. Biodiesel represented about 85% of total biofuels produced in the European Union (EU, 2020). Because biodiesel is produced from biomass, it is considered to be a renewable resource with the potential to provide a continuous and reliable source of energy. Furthermore, unlike conventional diesel production, biodiesel production does not produce waste (or produces very minimal waste) and is composed of 10-11% oxygen, trace amounts of nitrogen and it's sulphur-free (Raj *et al*., 2022). Over the last decade, biodiesel has greater increase in production than other biofuels (Gautam, 2024). Biodiesel production increased from 60.24 in 2022 to 66.69 million metric tons in 2023, which corresponds to an annual growth rate of 11.4% (Tondo Alves *et al*., 2024).

The production and consumption of fossil fuels have been known to produce high levels of contaminants, which cause environmental damage and consequently, contaminating water source directly or indirectly degrading natural reserves and food sources (Da Luz *et al.,* 2015). The global Liquefied Petroleum Gas (LPG), 2024 states that the LPG market was valued at USD 142.83 billion in 2023 and is projected to grow from USD 151.96 billion in 2024 to USD 281.29 billion by 2032, exhibiting a Compound Annual Growth Rate (CAGR) of 7.33% during the forecast period. This situation has initiated the research for alternatives to gasoline and diesel. An alternative diesel fuel must be technically possible, financially reasonable, friendly to the environment and readily available. Biodiesel, a mono-alkyl ester of long-chain fatty acids, is a potential substitute for petroleum diesel (Hassan and Vinjamur, 2014).

Biodiesel is an animal or vegetable oil-based diesel fuel that burns without the emission of much soot, carbon IV oxide and particulate matter (Oliveira and Da Silva, 2013). It is an alternative fuel that is obtained from renewable resources that burns in modified diesel engines with fewer environmental pollutants (Demshemino *et al.,* 2013). The inventor of biodiesel engines, Rudolf Christian Karl Diesel (1858-1913), demonstrated the use of vegetable oils as a substitute for diesel fuel in the 19th century (Orchard *et al.,* 2007). The belief was that the utilization of biomass fuel would become a reality as future versions of his engine are designed and developed. In other words, when a vegetable oil or animal fat chemically reacts with an alcohol, it can produce Fatty Acid Methyl Ester (FAME), a vegetable oil which can be used in diesel engines after some adjustment and modifications. Vegetable oils contain saturated hydrocarbons (triglycerides), which consist of glycerol and esters of fatty acids. In addition, fatty acids have different numbers of bonds and carbon chain lengths (Folayan *et al.,* 2019).

There are different kinds of production methods for alternative fuel, such as dilution, thermal cracking (pyrolysis), transesterification and micro-emulsification. However, transesterification is the best method for producing higher-quality biodiesel (Balat and Balat, 2010). The properties of biodiesel indicate whether or not it would be suitable for the performance, life and emission of the engine. The main properties of biodiesel include acid number, calorific value, viscosity, density, flash point, cloud point and pour point (Karmakar *et al.,* 2018).

Flamboyant (*Delonix regia*), which is a member of the Fabaceae family, is a perennial legume tree, grown in tropical and subtropical regions as an ornamental species because of its showy flowers. Abulude and Adejayan (2017) reported that all the parts of *Delonix regia* grown in Nigeria have been a waste since none of the parts have been exploited as foods and feeds, a fact that has informed the study of its potential for biodiesel production. The direct use of vegetable oils and its blends as fuel in diesel engines had been considered both unsatisfactory and impractical, primarily due to high viscosity, acid composition and free fatty acid content of such oils, as well as gum formation due to oxidation and polymerization during storage and combustion. A lot of research has been directed towards the production of biodiesel from different sources without looking at the application or usage in ICE without blending. This study produced biodiesel from flamboyant seed oil and evaluated its physicochemical and fuel properties and compared it against international biodiesel standards.

## MATERIALS AND METHODS

### Research Materials and Extraction Methods

The materials used in this work are flamboyant (*Delonix regia*) seeds. Reagents include: Methanol, n-hexane, pet-ether and sodium hydroxide (NaOH), all of analytical grade and were purchased from Lab Wares Company, Ilorin, Kwara State, Nigeria. Equipment used in this study includes a blender, retort stand, Soxhlet extractor, a labshop model 457 laboratory weighing scale with 0.01g accuracy, a conical flask and a glass jar. The procedure used for the oil extraction and biodiesel production is presented in the process flow diagram in Figure 1.

### Extraction of Oil from the Oil Seeds

The oils of flamboyant (*Delonix regia)* seeds were extracted using the solvent method of extraction, using hexane as solvent after Akpan *et al.* (2006).

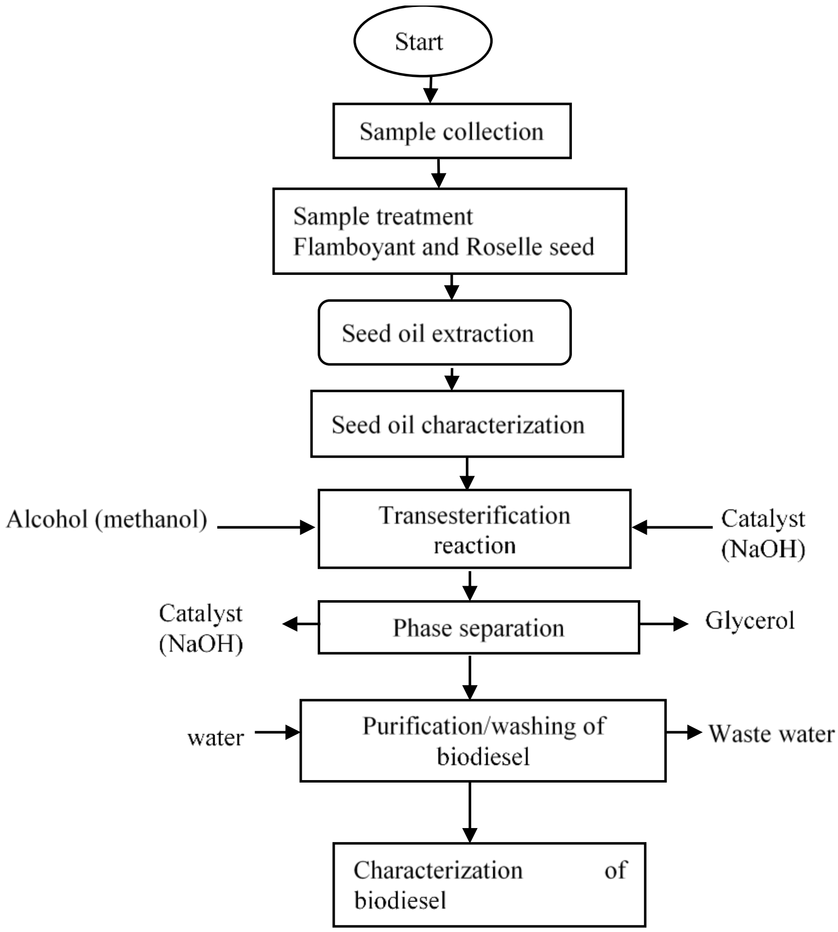


**Figure 1:** Process flow diagram for biodiesel production

The dried kernel samples were ground using an electric blender, after which the ground materials were sieved to fine particle sizes of 2 mm. The filter paper was filled with 20 g of sieved sample and inserted into the Soxhlet extractor. Fifty milliliters (50 ml) of petroleum ether were poured into a round-bottom flask and placed inside the round hole of the heating mantle that had been pre-set at 60 $^{o}$C.

As the solvent boils, solvent vapour flows up the distillation path, into the main chamber and up into the condenser where it condenses and drips down. The solvent fills the main chamber, dissolving some of the desired compound from the sieved sample inside the extractor. Once the chamber is almost full, it is emptied by the siphon, returning the solvent to the round bottom flask to begin the process again. This was allowed to continue for 4 hours to allow maximum extraction of the oil from the ground sample (Odetoye *et al.,* 2012).

The mixture of solvent and oil in the round-bottom flask was separated through a rotary vacuum evaporator (Oniya and Bamigboye, 2013). The sample oil collected was further filtered to remove solid impurities that may be present in the oil, followed by removal of the remaining moisture using a muffle furnace pre-set at 105 °C for 10 minutes. The volume of oil obtained was measured and recorded. The experiment was replicated three times and the average was taken. The percentage of the oil yield from the sample was determined from Equation 1 (Ana-Godson and Udofia, 2015).

$$\%\ Oil\ yield = \frac{weight\ of\ extracted\ oil\ (g)}{weight\ of\ seed\ (g)} \times 100 \qquad 1$$

**Characterization of Flamboyant (*Delonix regia*) Seed Oil**

The characteristics of flamboyant *(Delonix regia*) seed oil were obtained based on a published standard procedure to determine the acid value, density, kinematic viscosity and flash point of the oil (Khan, 2024).

**Determination of acid values**

The acid value of seed oil was determined following the ASTM D974 (2021) standard procedure. A measurement of 25 ml of diethyl ester and 25 ml of ethanol was mixed in a beaker. Furthermore, the mixture was then added to 5 g of oil in a conical flask and a drop of phenolphthalein as an indicator was added to the mixture and shaken vigorously. Then, 0.5 M NaOH was added to complete the reaction and neutralize the free fatty acids. The acid value of the oil was calculated as the percentage of acid present in terms of oleic acid and was determined using Equation 2 (Mahajan *et al*., 2006).

$$Acid\ value = 14.1 \times \frac{V_{\circ}}{W_{\circ}} \quad 2$$

Where $V_{\circ}$= Volume of 0.5 NaOH (ml), $W_{\circ}$= sample weight (g)

**Determination of Specific Gravity**

The specific gravity of the fuel sample was determined using the ASTM D1298 (2017) standard. An empty hydrometer was weighed using an electric weighing balance and denoted as $W_1$. The fuel sample of known volume at 15 °C was poured into the hydrometer and weighed as $W_2$. An equal volume of distilled water was weighed and denoted as Ww. The specific gravity (SG) of the fuel sample was calculated using Equation 3 (Kimilu *et al*., 2011)

$$S.G = \frac{W_2 - W_1}{W_w - W_1} \quad 3$$

Where $W_1$ = weight of empty hydrometer (g), $W_2$ = weight of hydrometer and fuel sample (g), $W_w$ = weight of equal volume of distilled water (g)

**Transesterification of Flamboyant Seed Oil:**

The reactant for the transesterification process was the raw seed oil sample. The transesterification reactions, which are for the production of fatty acid methyl esters, were placed in a batch reactor. The experimental setup consists of a neck flat bottom, 1000 ml glass vessel equipped with a thermometer and a water-cooled glass condenser to distil methanol out. Mixing of the reactants was controlled by a magnetic stirrer and heat was provided by a hot plate. The reactor was filled with 50 ml of oil and heated up to a temperature of 65°C as recommended by Alamu *et al.* (2007). A required quantity of methanol to oil ratio of 9:1, which is greater than the standard 3:1 required by stoichiometry as iterated by Bart *et al.* (2010), was added at a constant temperature of 65 ℃, which is below the boiling point of ethanol and maintained at 750 rpm throughout the experiment. Five grams (5 g) of NaOH catalyst was mixed with ethanol and stirred vigorously. The formed product was swiftly introduced into the oil in the reactor and stirred vigorously for 2 h until the end of the reaction. Fourteen milliliters (14 ml) of distilled water were added to the mixture and stirred continuously for 15 min to aid formulation and easy separation of biodiesel (Oniya and Bamgboye, 2013). After 1 h, the reaction mixture was cooled to room temperature in a water bath, filtered and transferred to a separating funnel and allowed to stand for 24 h. The two layers formed were separated by the process of sedimentation, where the upper and lower layers contain methyl ester and glycerol, respectively. The upper layer was washed with 50 ml deionized water twice, when the reaction was taking place and the organic layer was separated and analyzed to calculate fatty acid methyl ester content. The percentage of ester yield was calculated using Equation 4 (Ogunkunle *et al.,* 2017).

$$\%Y = \frac{V_e}{V_r} \times 100\% \qquad 4$$

Where Y = yield of ethyl-ester (%), Ve = volume of ethyl-ester produced ($m^3$), Vr = volume of raw oil used ($m^3$)

**Determination of Biodiesel Fuel Properties**

The produced biodiesel was characterized for its kinematic viscosity, density, flash point and Higher Heating value (HHV).

**Determination of biodiesel density**

The ASTM D1298 (2015) standard procedures were used to determine the density of the samples of biodiesel produced. The test method covers the laboratory determination of the density, relative density (specific gravity), or American Petroleum Institute (API) gravity of crude petroleum, petroleum products, or mixtures of petroleum and non-petroleum products normally handled as liquids using a glass hydrometer. An empty hydrometer was weighed with an electric weighing scale and denoted as $W_1$. The fuel sample at 15 °C was poured into the hydrometer to a known level and weighed as $W_2$ and the volume, V recorded. The density of fuel was calculated using Equation 5 as reported by Oniya (2010).

$$\partial = \frac{W_2 - W_1}{V} \qquad 5$$

Where $\partial$ = density, g/cm$^3$. $W_1$ = weight of empty hydrometer, g. $W_2$ = weight of hydrometer with fuel sample, g. V = volume of fuel hydrometer, g/cm$^3$

**Determination of biodiesel kinematic viscosity**

The ASTM D445 (2017) method was used to determine the kinematic viscosity of the oil samples. The measurements were made utilizing a calibrated glass capillary viscometer and a SYD-265 kinematic viscosity tester. The temperatures were read with a mercurial thermometer within the thermostat and a viscometer with an accuracy of ±0.1 °C and rested for 5 min when the temperature reached its equilibrium value. To get a defined temperature between 10 and 25 °C, an ice bag was placed in a temperature-controlled water bath. A stopwatch with an accuracy of 0.01s was used to record the time that a calibrated glass capillary viscometer took to transfer samples between the bubbles. For every test in the study, each sample was run in triplicate. To obtain kinematic viscosity in mm$^2$s$^{-1}$, the efflux time was multiplied by the viscometer constant specified by the manufacturer using Equation 6 (Corach *et al.,* 2021).

$$V = kt \qquad 6$$

Where V = viscosity (m$^2$/s), k = the constant calibration of the viscometer (m$^2$/s$^2$), t = time taken (s)

**Determination of Biodiesel Flash Point**

The flash point was measured using the ASTM D93 (2020) method using the Pensky-Martens closed cup apparatus. The test cup was filled with the test specimen up to the filling mark inside the cup. The temperature of both the test cup and the test specimen was maintained and a syringe was used to remove excess test specimen. The entire assembly was positioned into the apparatus and the test cover was then placed on the test cup and properly locked. The test flame was ignited and adjusted to a diameter of 4.8 mm (0.189 in). The stirring device operated at 250 ± 10 rpm in a downward direction, while heat was applied at a rate that increased the temperature by 1.6°C per minute, as indicated by the temperature measuring device. The observed flash point was recorded as the temperature at which the ignition source application caused a distinct flash inside the test cup. A sample was considered to have flashed when a large flame appeared and instantaneously spread over the entire surface of the test specimen. The ambient barometric pressure at the time of testing was also recorded.

**Determination of Higher Heating Value (HHV)**

The ASTM D5865M (2019) procedure was used to determine the calorific value of the produced biodiesel fuels. This test method determines the gross calorific value of biodiesel using an adiabatic combustion calorimeter. A known amount of fuel sample was burned in an adiabatic combustion calorimeter. The air was replaced by pure oxygen. A maximum deflection of the galvanometer on the control box was recorded after using the samples. The effective heat capacity of the system was also determined using the same procedure, but with pure and dry benzoic acid as the test fuel. The heating value was calculated using Equation 7 (Sivaramakrishnan and Ravikumar, 2012).

$$HV = \frac{Y(a_3 - a_1)}{Z} \quad 7$$

Where HV = heating value, KJ/kg. $a_1$ = Galvanometer deflection without sample, A. $a_3$ = Galvanometer deflection with sample, A. Y = Calibration constant (defined in Equation 10). Z = mass of fuel sample, g. The calibration constant (Y) is given by Equation 8

$$Y = \frac{6.32w_1}{a_2 - a_1} \quad 8$$

Where Y = Calibration constant, $a_1$ = Galvanometer deflection without sample, A. $a_2$ = Galvanometer deflection with benzoic sample, $W_1$ = mass of benzoic acid (g).

**Determination of Carbon, Hydrogen and Nitrogen Content.**

ASTM D5291 (2017) standard was used to determine the carbon, hydrogen and nitrogen contents of fuel samples. The method covers the instrumental determination of carbon, hydrogen, and nitrogen in laboratory samples of petroleum products and lubricants concurrently in a single instrumental procedure. The fuel sample was converted to carbon dioxide, water vapor and elemental nitrogen, respectively. The conversion of the subject materials to their corresponding gases takes place during the combustion of the sample at an elevated temperature in an atmosphere of purified oxygen. Here, a variety of gaseous materials are produced, including; Carbon dioxide from the oxidation of organic and elemental carbon, hydrogen halides from organic halides (and organic hydrogen, as required), water vapor from the oxidation of organic hydrogen and the liberation of moisture, nitrogen and nitrogen oxides from the oxidation of organic nitrogen, and sulphur oxides from the oxidation of organic sulphur. The combustion product gas stream, after full oxidation of component gases, is passed over heated copper to remove excess oxygen and reduce $NO_x$ to $N_2$ gas. The gases are then passed through a heated chromatographic column to separate $N_2$, $CO_2$, and $H_2O$ in that order. The individual eluted gases are measured by a thermal conductivity detector.

**Determination of Oxygen Content**

The oxygen content was determined using the ASTM D5622 (2017) standard method. A fuel sample of 1 to 10 ml is injected by syringe into a 950 to 1300 °C high-temperature tube furnace that contains metallized carbon. Oxygen-containing compounds were pyrolyzed, and the oxygen was quantitatively converted into carbon monoxide. A carrier gas, such as nitrogen, helium, or a helium/ hydrogen mixture, sweeps the pyrolysis gases into any of the four downstream systems of reactors, scrubbers, separators, and detectors for the determination of the carbon monoxide content, hence of the oxygen in the original fuel sample. The result is reported as mass% oxygen in the fuel.

**Statistical Analysis**

The data obtained from the characterization of the biodiesel produced from the flamboyant seed oil was analysed using one-way analysis of variance section of the Minitab version 17.1.0 software by Minitab Inc. This is to determine whether there are significant differences among the means of the data obtained for the characteristics of the biodiesel produced.

## RESULTS AND DISCUSSION

**Physicochemical properties of flamboyant seed oil**

The physicochemical properties of flamboyant seed oil are as shown in Table 1. The acid value of flamboyant seed oil is 13.17 mgKOH/g. The value obtained in this study was lower than the 60.3 mgKOH/g obtained for oil from phoenix tree seed (Li *et al.,* 2023). Sharma and Jain (2015) on the determination of the acid value of different seed oils concluded that the higher the acid value, the higher the oxidation of the oil and if the acid value of a substance is known, the quality of the substance can be determined. The specific gravity of flamboyant seed oil is 1.05. The value obtained in this study was higher than the 0.88 reported by Bamgboye and Oniya (2012) for loofah seed oil. Ramesh *et al.* (2008) and Ramah *et al.* (2010) obtained 0.91 and 0.92 for the specific gravity of soybean and rapeseed oils, respectively. The result obtained in this study implies that the oil obtained from flamboyant seed is denser than water, thereby it will not float on water.

A flash point of 106 °C was obtained for flamboyant seed oil. The result showed that the flamboyant seed oil is safer in terms of handling and storage and less hazardous. The value obtained in this study is lower than the 206 °C obtained by Eman *et al.* (2020) for roselles seed oil extracted using a modified solvent extraction method. The difference in values may be as a result of modification in the method used for extraction. The value of viscosity obtained for flamboyant seed oil was 5.89 $mm^2/s$. The value obtained was slightly lower than that of loofah oil (6.2 $mm^2/s$) and higher than that of groundnut oil of 3.9 $mm^2/s$ (Bamgboye and Oniya, 2012). The higher viscosity could be because flamboyant seed oil has a higher molecular weight of triglyceride molecules (Ezugwu *et al.,* 2019). The viscosity would significantly reduce with the process of pre-heating and transesterification as reported by Bamgboye and Oniya (2013).

**Table 1: Physicochemical Properties of Flamboyant Seed Oils**

| Property | Flamboyant seed oil |
|---|---|
| Acid value (mgKOH/g) | 13.17 |
| Specific gravity | 1.05 |
| Flash point (°C) | 106.00 |
| Viscosity @ 28 °C | 5.89 |

**Properties of Flamboyant Biodiesel**

The properties of flamboyant biodiesel compared with petroleum diesel (AGO) and the ASTM standard for pure biodiesel (B100) are presented in Table 2.

**Acid Value**

Table 2 showed that Flamboyant biodiesel has a higher acid value (3.37 mgKOH/g) than petroleum diesel (AGO) range of 0.01 - 0.5 (max) mgKOH/g, indicating a higher concentration of free fatty acids, which is generally considered acceptable for fuel use. The acid value of Flamboyant biodiesel obtained from this research is lower than the 8.13 mgKOH/g recorded by Ezugwu *et al.* (2019).

**Specific Gravity**

The result presented showed that at 15 ºC, Flamboyant biodiesel has a higher specific gravity of 1.06 than petroleum diesel (AGO), which ranged between 0.82 - 0.87 and the ASTM standards of 0.88, as shown in Table 2. The Specific gravity of the Flamboyant biodiesel obtained from this research is relatively higher than the 0.74 recorded by Ezugwu *et al.* (2019) at 30 ºC for Flamboyant biodiesel. The specific gravity values of jatropha methyl ester, soybean ethyl ester and sunflower ethyl ester were reported as 0.88, 0.92, and 0.86, respectively, by Rahman *et al.* (2010), Ramash *et al.* (2002) and Rao *et al.* (2008). The specific gravity of the flamboyant-AGO - AGO blends appears to be more in line with the ethyl ester value of soybeans. The difference in specific gravity values can be attributed to the varying temperatures at which the measurements were taken.

**Flash Point**

Flash points of 120°C were recorded for flamboyant seed oil biodiesel, as shown in Table 2. The value is higher than the AGO value of 52 and the ASTM D6751 of 93. This result is in line with Binhweel *et al.* (2021) report on flash point values of different biodiesel sources, ranging between 118.5 to 183°C for coconut and rubber biodiesel, respectively. Ramadhas *et al.* (2004), flash points of sunflower, soybean and peanut biodiesels were 183, 178, and 176 °C, respectively. These were higher than those of the flamboyant biodiesel obtained in this study (120 °C). Campus (2011) also reported that biodiesel has a flash point that is considerably higher than petroleum-based diesel; that is fire hazard associated with transportation, storage and utilization of biodiesel is much less than that of petroleum-based diesel.

**Kinematic Viscosity**

Table 2 showed that at 40 °C, Flamboyant biodiesel has a kinematic viscosity (1.663 $mm^2/s$), which has lower viscosity than petroleum diesel AGO (1.9 - 4.1 $mm^2/s$) and standard ASTM D6751 (1.9 - 6.0 $mm^2/s$). The obtained value was less than the corresponding values of 4.9, 4.5, 5.7 and 4.6 $mm^2/s$ for peanut, soyabean, palm oil and sunflower ethyl ester, respectively (Ramadhas *et al.,* 2004). While Binhweel *et al.* (2021) reported that the kinematic viscosity of pond algae biodiesel, 5.82 $mm^2/s$ and coconut biodiesel, 3.1435 $mm^2/s$, which are higher than that obtained in this report.

**Density**

Results presented in Table 2 showed that Flamboyant biodiesel has slightly higher density (0.94 $g/m^3$) than petroleum diesel AGO (0.82-0.87 $kg/m^3$) and standard ASTM D6751 (0.85 $g/m^3$), which may affect fuel storage and handling. The density recorded for flamboyant biodiesel in this research is higher than 0.78 and 0.874 $g/m^3$ of Ezugwu *et al.* (2019) and Arowosafe *et al.* (2022). Denser fuels provide greater energy per gallon and since fuel is sold volumetrically, the higher the density, the greater the potential energy (Demirel and Demirel, 2012).

**Table 2: Physicochemical Properties of Flamboyant Biodiesel Compared with Petroleum Diesel and B100 Biodiesel Standards**

| Biodiesel property | Flamboyant biodiesel | Petroleum diesel ASTM D975 | ASTM D6751-24 (Grade 2-B S15) |
|---|---|---|---|
| Acid value, mgKOH/g | 3.37 | 0.01 | 0.5 (max) |
| Specific gravity | 1.06 | 0.811 – 0.857 | 0.88 |
| Flash point, $^oC$ | 120 | 52 | 93 |
| Kinematic viscosity @ 40 $^oC$, $mm^2/s$ | 1.663 | 1.9-4.1 | 1.9-6.0 |
| Density, $g/cm^3$ | 0.94 | 0.85 | 0.82-0.87 |
| Higher Heating Value, MJ/kg | 15.60 | 45.6 | 45.22 |
| Carbon Content, % | 41.36 | 0.35 | 25 |
| Hydrogen Content, % | 5.45 | | 12 |
| Oxygen Content, % | 41.77 | | 11 |
| Nitrogen Content, % | 0.06 | | |
| Sulphur Content, % | 0.05 | | 0.0015 - 0.05 |

**Higher Heating Value**

Compared to the values of 45.22 MJ/kg stated for B100 biodiesel in the ASTM D6751 standard and 45.6 MJ/kg for Petroleum diesel AGO, the higher heating value for flamboyant biodiesel, as shown in Table 2, was 15.60 MJ/kg. This value is also lower than the values of soybeans (33.5 MJ/kg), sunflower (33.5 MJ/kg), linseed (35.3 MJ/kg) and peanut biodiesel (33.6 MJ/kg) reported by Ramadhas *et al.* (2004) and that reported by Binhweel *et al.* (2021) for camelina, rubber, mustard, pond algae, *Jatropha curcas* L, Sunflower and oil palm biodiesels of 52.2, 42.372, 41.91, 40.8, 40.79, 40.6 and 34.41 MJ/kg, respectively.

**Carbon, Hydrogen, Oxygen, Nitrogen and Sulphur Contents**

The result presented in Table 2 showed that flamboyant biodiesel has hydrogen (5.45 %), oxygen (41.77 %), sulphur (0.05 %), carbon (41.36 %) and nitrogen (0.06 %) contents. ASTM D6751 standard and Petroleum diesel (AGO) for carbon content are 25 and 0.35 %, respectively.

## CONCLUSION

Oil was extracted from flamboyant (*Delonix regia)* seeds and the biodiesel produced from its seed oil was found to be within the range specified by the ASTM standard for B100 biodiesel. The physicochemical properties of the oil indicated that flamboyant seed oil has an acid value of 13.17 mgKOH/g, showing that it is less prone to oxidation. The specific gravity, viscosity, flash point and density of the biodiesel are high, but it has lower kinematic viscosity and higher heating values. This suggests that the biodiesel derived from flamboyant seed possesses qualities beneficial for combustion but requires adjustments, especially in terms of improving its energy content and reducing its density, for direct application in internal combustion engines (ICE).

## REFERENCES

Abulude, F. O., and Adejayan, A. W. (2017). Nutritional values of flamboyant *(Delonix regia) seeds obtained in Akure, Nigeria (No e2764v1)*. Peer J Preprints.

Akpan, U. G., Jimoh, A., and Mohammed, A. D. (2006). Extraction, characterization and modification of castor seed oil. *Leonardo Journal of Sciences,* 8(1): 43-52.

Alamu, O. J., Waheed, M. A. and Jekayinfa, S. O. (2007). Biodiesel production from Nigerian palm kernel oil: effect of KOH concentration on yield. *Energy for Sustainable Development*, **11**(3): 77-82.

Ana-Godson, R. E. E. and Udofia B. G. (2015). Characterization of oil and biodiesel produced from *Thevetia peruviana* (yellow oleander) seeds. *International Journal of Sustainable and Green Energy*, **4**(4): 150-158.

Arowosafe, K. O., Bamgboye, A. I., Adesanya, A. A., Odugbose, B. D., Olannye, U. D. and Fatoye, O. V. (2022). Biofuel production from locally sourced roselle (Hibiscus Sabdariffa L.) seed oil using the transesterification process. *Nigerian Journal of Technology*, *41*(1), 191-196.

ASTM D1298 (2015). Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method; American Society for Testing and Materials: West Conshohocken, PA.U.S.A.

ASTM D445 (2012). Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids. American Society for Testing and Materials: West Conshohocken, PA.U.S.A.

ASTM D5291. (2017) Standard Test Methods for Instrumental Determination of Carbon, Hydrogen and Nitrogen in Petroleum Products and Lubricants. American society for testing and materials: West Conshohocken, PA.U.S.A.

ASTM D5622 (2017). Standard Test Methods for Determination of Total Oxygen in Gasoline and Methanol Fuels by Reductive Pyrolysis. American Society for Testing and Materials: West Conshohocken, PA.U.S.A.

ASTM D5865 (2019) Standard Test Method for Gross Calorific Value of Coal and Coke. American Society for Testing and Materials: West Conshohocken, PA.U.S.A.

ASTM D6751. (2008). Standard specification for biodiesel fuel (B100) blend stock for distillate fuels. In: Annual Book of ASTM Standards, ASTM International, West Conshohocken.

ASTM D93. (2018)- Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester. American Society for Testing and Materials: West Conshohocken, PA.U.S.A.

ASTM D974. (2021). Standard Test Method for Acid and Base Number by Color-Indicator Titration. American society for testing and materials. West Conshohocken, USA.

Balat, M. and Balat, H. (2010). Progress in biodiesel processing. *Applied energy*, **87**(6): 1815-1835.

Bamgboye, A. I. and Oniya, O. O. (2012). Fuel properties of loofah (Luffa cylindrica L.) biofuel blended with diesel. African Journal of Environmental Science and Technology, 6(9), 346-352.

Bart, J. C., Palmeri, N. and Cavallaro, S. (2010). Transesterification Processes for Biodiesel Production from Oils and Fats. *Biodiesel Science and Technology*. pp 285-321.

Binhweel, F., Bahadi, M., Pyar, H., Alsaedi, A., Hossain, S. and Ahmad, M. I. (2021, May). A comparative review of some physicochemical properties of biodiesels synthesized from different generations of vegetative oils. In *Journal of Physics: Conference Series* (Vol. 1900, No. 1, p. 012009). IOP Publishing.

Campus, P. (2011). Comparative analysis of fuel characteristics of biodiesel produced from selected oil-bearing seeds in Nigeria. *European Journal of Scientific Research*, *58*(2), 238-246.

Corach, J., Sorichetti, P. A. and Romano, S. D. (2021). Electrical properties and kinematic viscosity of biodiesel. *Fuel*, *299*, 120841.

Da Luz, C. D. S. C., Mainier, F. B. and Monteiro, L. P. C. (2015). Evaluation of Oilseeds for Biodiesel Production. *American Journal of Environmental Engineering*, **5**(2): 47-51.

Demirbas, A., Bafail, A., Ahmad, W. and Sheikh, M. (2016). Biodiesel Production from Non-Edible Plant Oils. *Energy Exploration and Exploitation*, **34**(2): 290-318.

Demirel, Y. and Demirel, Y. (2012). Energy and energy types. *Energy: Production, conversion, storage, conservation* and *coupling*, 27-70.

EU (2020). Biofuels Annual Report. European Union Available at: https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Biofuels%20Annual_The%20Hague_European%20Union_06-29-2020

Ezugwu, M. U., Obidiegwu, M. U., Ezugwu, C. H., Dasofunjo, K. and Berinyuy, E. B. (2019). Synthesis and characterization of alkyd resin from Delonix Regia (Flamboyant) seeds. *Journal of Polymer Science and Applications, 3(1):100117*.

Folayan, A. J., Anawe, P. A. L., Aladejare, A. E. and Ayeni, A. O. (2019). Experimental Investigation of the Effect of Fatty Acids Configuration, Chain Length, Branching and Degree of Unsaturation on Biodiesel Fuel Properties Obtained from Lauric Oils, High-Oleic and High-Linoleic Vegetable Oil Biomass. *Energy Reports*, ***5***: 793-806.

Gautam, A., Pant, M., Pant, G., and Kumar, G. (2024). Second-generation biofuels: Concepts, applications, and challenges. *Microbial applications for environmental sustainability*, 277-304.

Hassan, S. Z. and Vinjamur, M. (2014). Parametric Effects on Kinetics of Esterification for Biodiesel Production: A Taguchi Approach. *Chemical Engineering Science*, **110**: 94-104.

Karmakar, R., Rajor, A., Kundu, K. and Kumar, N. (2018). Production of Biodiesel from Unused Algal Biomass in Punjab, India. *Petroleum Science*, **15**(1): 164-175.

Khan, I. U. (2024). Biodiesel production and selected fuel qualities from prospective non-edible oils: Hevea brasiliensis, Madhuca longifolia, Azadirachta indica, and Gossypium hirsutum. *International Journal of Green Energy*, *21*(13), 3054-3071.

Kimilu, R. K., Nyang'aya, J. A. and Onyari, J. M. (2011). The effects of temperature and blending on the specific gravity and viscosity of Jatropha methyl ester. ARPN J Eng Appl Sci, 6(12), 97-105.

Li, B., Wang, F., Li, K. and Sun, S. (2023). Biodiesel preparation from high acid value phoenix seed oil using Eversa transform 2.0 as a novel catalyst. *Biomass Conversion and Biorefinery*, *13*(11), 9821-9830.

Mahajan, S., Konar, S.K. and Boocock, D. G. B. (2006). Determining the acid number of biodiesel. *Journal of the American Oil Chemists' Society*, 83(6), 567-570.

Odetoye, T. E., Ogunniyi, D. S. and Olatunji, G. A. (2013). Studies on the Preparation of Parinari Polyandra Benth Seed Oil Alkyd Resins. *Journal of Applied Polymer Science*, **127**(6): 4610-4616.

Ogunkunle, O., Oniya, O. O. and Adebayo, A. O. (2017). Yield Response of Biodiesel Production from Heterogeneous and Homogeneous Catalysis of Milk Bush Seed (Thevetia peruviana) Oil. *Energy and Policy Research*, **4**(1): 21-28.

Oliveira, L. E. and Da Silva, M. L. C. P. (2013). Comparative Study of Calorific Value of Rapeseed, Soybean, Jatropha Curcas and Crambe Biodiesel. *Renewable Energy and Power Quality Journal*, **1**(11): 679-82.

Oniya, O. O. (2010). Biodiesel Production from Loofah and Groundnut Oils. *Unpublished Ph.D thesis, Department of Agricultural Engineering, University of Ibadan*, Nigeria.

Oniya, O. O. and Bamgboye, A. I. (2013). Production of Biodiesel from Groundnut *(Arachis hypogea, L.*) Oil. *Agricultural Engineering International: CIGR Journal*, 16(1): 143－150.

Orchard, B., Denis, J. and Cousins, J. (2007). Developments in Biofuel Processing Technologies. *World Pumps*, ***2007***(487): 24-28.

Rahman, K. M., Mashud, M., Roknuzzaman, M. A. G. A. and Al Galib, A. (2010). Biodiesel from Jatropha oil as an alternative fuel for diesel engines. International Journal of Mechanical and Mechatronics (IJMME-IJENS), 10(3), 1-6.

Raj, S. P., Solomon, P. R., Thangaraj, B., Raj, S. P., Solomon, P. R. and Thangaraj, B. (2022). Standards for Biodiesel. *Biodiesel from Flowering Plants*, 633-663.

Ramadhas, A. S., Jayaraj, S., and Muraleedharan, C. (2004). Use of Vegetable Oils as I.C. Engine Fuels: A Review. *Renewable Energy,* 29: 727-742.

Ramesh, D.; Samptatraja, A. and Venkacha, P. (2002). Production of Biodiesel using a Pilot Biodiesel Plant with Jatropha. Agric Engineering College and Research Institute, Rami Nadu Agricultural University.

Rao, Y. H., Voleti, R. S., Hariharan, V. S. and Raju, A. S. (2008). Jatropha oil methyl ester and its blends are used as an alternative fuel in diesel engines. International Journal of Agricultural and Biological Engineering, 1(2), 32-38.

Sharma, S. and Jain, V. K. (2015). Acid value of various domestic uses of oil. *Research Journal of Science and Technology*, *7*(2), 109-110.

Sivaramakrishnan, K., and Ravikumar, P. (2012). Determination of cetane number of biodiesel and its influence on physical properties. *ARPN Journal of Engineering and Applied Sciences*, *7*(2), 205-211.

Tondo Alves, C., Sergio, H., Lilian, L. and Nani Guarieiro, L. (2024). Biodiesel Technologies: Recent Advances, New Perspectives, and Applications. IntechOpen. doi: 10.5772/intechopen.1007782