FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 9 No. 2, February, 2025, pp 209 - 215
DOI: https://doi.org/10.33003/fjs-2025-0902-3164

PHYSICO-CHEMICAL PROPERTIES OF BIODIESEL DERIVED FROM *LANNEA MICROCARPA* OIL: A COMPARATIVE ANALYSIS WITH FOSSIL DIESEL

***[1]Wada, I., [2]Yahaya, D. B. and [2]Garba, I.**

[1]Department of Mechanical Engineering Technology, Federal Polytechnic Kaura-Namoda, Zamfara State, Nigeria
[2]Department of Mechanical Engineering, Bayero University, Kano, Nigeria

*Corresponding authors' email: wadaasy@gmail.com Phone: +234 8069243520

ABSTRACT

In the present study, non-edible oil of *Lannea microcarpa* was extracted through the use of a mechanical press and biodiesel was produced from the extracted oil in two steps reactions of esterification and alkali-catalyzed trans-esterification. The percentage oil and biodiesel yield were found to be 46.15% and 90.63%wt respectively. The physico-chemical properties of the biodiesels were investigated and comparatively analysed to ascertain the suitability of this biodiesel to replace fossil diesel. The physico-chemical properties evaluated were also compared with reported values in the literature. The results showed that *L. microcarpa* biodiesel had density (0.8965g/cm^3), kinematics viscosity (6.00 mm^2/s), cetane number (41.98), flash point (128^{0}C), fire point (140^{0}C), calorific value (38.5 MJ/kg), cloud point (5^{0}C), pour point (-9.5^{0}C), iodine value (120gI/100g), saponification value (240mgKOH/g), carbon residue (0.50%) and ash content (0.03%). It was revealed that, seven out of the twelve assessed properties conformed to ASTM standard but iodine value, calorific value, cetane number, carbon residue and ash content deviated slightly with negligible differences. It was also noted that, the density, viscosity, cetane number, calorific value, ash content and carbon residue of fossil diesel were found to be slightly better than those of the biodiesel. Conversely, the biodiesel exhibited slightly better cloud point, pour point, flash point, and fire point than fossil diesel. Hence, *Lannea microcarpa* biodiesel considered to met the specified standard recommendations for suitably used in conventional diesel engines.

Keywords: *Lannea microcarpa* seed oil, Biodiesel, Physio-chemical properties, ASTM, Diesel

INTRODUCTION

Nigeria depends mainly on crude oil in its transportation, agriculture, automotive and industrial sectors among others, and its current energy demand is insatiable. Nigerian oil sector is associated with a set of problems such as the high rate depletion of crude oil reserves, economic problems, price instability, global politics, negative environmental effect and health hazards, and, more recently, the removal of fuel subsidies, have motivated the move away from over-reliance on fossil fuel, thus creating global interest in alternative renewable and sustainable sources of fuel that would surmount these challenges. Among the possible different alternative of energy sources that will wholly or partially substitute crude oil is biofuel, especially in a country with a huge biomass potential like Nigeria. The conversion of readily available sources of biomass to produce different types of biofuels such as biodiesel, bioethanol, biomethanol, biogas, and biohydrogen to address the future energy needs and climate change is timely. Therefore, this research work is justifiable by all the aforementioned problems. Biodiesel has been proposed as a good complement and replacement of fossil diesel because of the overwhelming physico-chemical properties similar to fossil diesel in addition to its good lubricity, biodegradability, non-toxicity, renewability, and eco-friendliness when used in diesel engine (Suleiman *et al*., 2023; Maulidiyah *et al.*, 2017).

Biodiesel (methyl ester) is a renewable and biodegradable source of energy derived from vegetable oils or animal fats. It can be used as an alternative to diesel fuel in Compression ignition (C.I) engine in form of a suitable blend or in unblended form with no or little modification and produced the same or better performance compared to ordinary diesel fuel (Lawan *et al*., 2019; Mofijur *et al.*, 2016; Awulu *et al.*, 2015). Different types of plants seed oil have the potential to be used as feedstock for biodiesel production, among the neglected and underutilized local seeds for possible use is *Lannea microcarpa* (African grapes). This non-edible oil feedstock is abundant, low-cost and do not compete with food crops, and hence do not pose any threat to national and global food security; the seeds samples are not economically viable and are often discarded as waste into the environment (Warra, 2019; Yunus *et al*., 2013). Plant seeds' oil content is one of factors considered for suitability of a feedstock for biodiesel production; similar researches revealed that *Lannea microcarpa* seed had an oil yield of 41.2%, 41% and 59.21% as reported by Yunusa *et al*., (2013), Nafi'u *et al.*,(2011) and Warra, (2019) respectively. These oil yield was reasonable compared to other non-edible oil feedstock such as mango seed oil which reported to have 14% (Musa *et al*., 2014), and *Acacia nilotica* 20% (Adhikesavan *et al*., 2015).

The physico-chemical properties of fuel are specifications that define and set the quality standards for biodiesel (Samir and Rehab, 2015). For biodiesel, physico-chemical properties are a set of property specifications measured by American Society for Testing and Material (ASTM) test method such as ASTM D6751.This specification must be met for a biodiesel to be used directly or in blended form with any petroleum-derived fuel in compression ignition engines (Kaisan *et al*., 2017). These properties are termed physico-chemical properties which include but not limited to: density, kinematic viscosity, iodine value, saponification, flash point, fire point, pour point, cloud point, calorific value, cetane number, carbon residue and ash content. Similar researches have explore some of the physic-chemical properties of *Lannea micropcarpa* seed oil biodiesel (Agarry *et al.*, (2013); Kaisan *et al.*, (2013), Yunus *et al*., (2013) and Nafiu *et al*., (2011)). However none of these or any other published research in literature that determined and comparatively analyzed up to 12 physico-chemical properties of biodiesel from this feedstock. There is therefore a need to determine the physico-chemical properties of biodiesel from *Lannea microcarpa* seeds oil and assess its potentials to replace fossil diesel. Result from this study is

expected to contribute to the existing database of locally available alternative biofuel resources with the aim of reforming the global energy and environmental predicaments.

MATERIALS AND METHODS

Materials

All chemical reagents used in this study were of analytical grades. They included: methanol, Sodium hydroxide, sulphuric acid, propane-2-ol, ethanol, wij's solution, potassium hydroxide, phenolphthalein indicator, distilled water and potassium iodide. The equipments used include: *Lannea microcarpa* seed, screw press milling machine, viscometer, magnetic stirrer, burettes, beakers, retort stand, conical flasks, separating funnels, thermometer, cooling bath, stop watch, electric weighing balance, pipette, bomb calorimeter, pensky martin closed cup tester, refrigerator, crucible, electric furnace, and cetane meter.

Methods

Seed collection

In this work, the seed sample used is botanically called *Lannea microcarpa;* it is also referred to as wild grapes or African grapes in English and "Faru" in Hausa, the main language in Northern Nigeria. The sample was obtained from Eka forest in Rimi local government area of Katsina State in Nigeria.

Oil Extraction Procedure and Biodiesel Production

The preliminary seed preparations and oil extraction was carried out at National Research Institute for Chemical Technology (NARICT), Zaria Kaduna State, Nigeria. While the biodiesel production and analysis was conducted at Chemical Engineering Laboratory of Ahmadu Bello University, Zaria Kaduna State, Nigeria.

Lannea microcarpa seed sample was washed and dried, oil was extracted from the sample using the mechanical press engine driven expeller as reported by (Sani *et al*., 2018; Kaisan *et al.,* 2013). The oil yield was computed as 46.15% using the relation reported by (Ochi *et al*, 2020; Hassan *et al.,* 2015). The oil was degummed by water, and the free fatty acid of the oil was determined as 15.792%, which was later reduced to 0.742% by acid-catalysed esterification process (Chai *et al.,* 2014). Biodiesel was produced by trans-esterification reaction between the *Lannea microcarpa* oil and methanol in the presence of sodium hydroxide as catalyst; at a reaction temperature of 60^0C - 65^0C (Ochi *et al*., 2020, Kaisan *et al*., 2013). The percentage of the biodiesel yield in this research was computed as 90.63% using the relation reported by (Ochi *et al*., 2020).

Determination of the Physico-chemical Properties of Lannea microcarpa seed oil biodiesel

Laboratory tests for determination of the physico-chemical properties of the produced biodiesel were carried out using the ASTM D-6751 standard test procedure in triplicates to ensure data reliability and average value were recorded.

Determination of Density

Density is expressed as the mass of the substance divided by the volume of the same substance.

So density is calculated according to (Samir and Rehab, 2015) in Equation 1.

$$\text{Density} = \frac{\text{mass of the biodiesel sample}}{\text{Volume of the biodiesel sample}} \quad (1)$$

Determination of Kinematic Viscosity

The test was conducted according to ASTM D445. In this method, 20ml of the fuel sample was poured into a capillary tube of a calibrated Ostwald viscometer and inserted in viscometer bath, where it was then heated at 40^0 C for 30 minutes. The time required the fuel sample to flow under gravity between two marked points in the tube was recorded. The viscosity (V) in m^2/s was calculated by multiplying the time of flow with Ostwald viscometer calibrated constant as in Equation 2 (Sani *et al*., 2018; Nurun *et al*., 2015; Nafi'u *et al*., 2011).

$$V = kt \quad (2)$$

Where: V = Viscosity (m^2/s); k = the constant calibration of the viscosity (m^2/s^2); t = time (s)

Determination of Saponification Value

2g of the biodiesel sample was into conical flask and mixed with alcoholic potassium hydroxide (50 ml, 0.5%). The mixture was heated for 30 min and stirred vigorously. It was allowed to cooled and titrated with 0.5M of hydrochloric acid solution using phenolphthalein as an indicator; the titration was continued to the end point where the pink colour just disappeared. A blank titration using the same procedure was performed without the biodiesel sample (Samir and Rehab, 2015). The saponification value of the samples was calculated from the expression reported by (Samir and Rehab, 2015) in Equation 3.

$$\text{S.V} = \frac{(\text{B}-\text{S})\text{X A}}{\text{W}} \quad (3)$$

Where; A = amount of fatty acid present in g/dm^3

S.V = saponification value (mgKOH/g),

B = Blank titre,

S = Sample titre ,

W = mass of the biodiesel sample

Determination of Iodine Value

In the method, 1g of the biodiesel sample, 10cm^3 ethanol and 5cm^3 of wij's solution were mixed and another 10cm^3 of 10% potassium iodide solution was added to the mixture and shaken vigorously. The prepared solution was titrated with 0.1N sodium thiosulphate (vi) using 1 mL of 0.5% starch solution as indicator until the blue colour just disappeared. A blank titration without the biodiesel was conducted in the same procedure. The iodine value was calculated using the relation from Equation 4 (Lawan *et al*., 2019; Sadiq, 2016;).

$$\text{I.V} = \frac{(\text{B}-\text{S})\text{X } 12.69 \text{ X N}}{\text{W}} \quad (4)$$

Where;

W= weight of the biodiesel,

B= blank titre;

S= sample titre

N = normality of Sodium thiosulphate (vi)

Determination of Flash and Fire Points

Both flash and fire points were determined using Pensky Martin closed cup apparatus according to ASTM D93. In the method, a brass test cup fitted with cover was filled with the biodiesel sample and inserted in to an automated Pensky Martens closed cup tester which has a stirrer and thermometer. The sample in the cup tester was continuously heated and vigorously stirred to ensure uniform distribution of heat, the temperature of the fuel sample was monitored using a digital thermocouple thermometer. After every 1^0C temperature rise, a naked flame was passed over the test apparatus for a split second. Once the flash point temperature is reached, the vapour was ignited and a detectable flash in the form of sound that does not support combustion appeared. The samples was subjected to further heating beyond the flash point until a temperature at which the fuel vapour supports combustion (catches fire and stays for at least five seconds)

was reached and recorded as the fire point (Sani *et al*; 2018; Nurun *et al*., 2015).

Determination of Cloud and Pour Points

Cloud and pour points were determined according to ASTM D2500 using a cylindrical test tube of 12cm height and 3cm in diameter. A 5ml of the biodiesel sample was poured into a test tube, and a thermometer of range (−30°C to 20°C) was inserted through a cork to cover the mouth of the test tube. The thermometer was positioned just 2mm to the bottom of the test tube and the whole test set up was placed in a refrigerator. The test tube was inspected at every 2-minute intervals until some traces of cloudy suspension first appeared in the test tube; the temperature at which the sample became cloudy was recorded as its cloud point. The test tube containing the sample was further cooled and tilted at intervals to check for flow of biodiesel until no flow was observed and the sample solidified. The temperature at that point was recorded as pour point (James *et al,* 2021; Sani *et al.,* 2018).

Determination of calorific value

The calorific value of the fuel was determined according to ASTM D5865, using a SLFA-1598, Horiba bomb calorimeter. In the method, 100ml of the fuel sample would be placed in a crucible, the crucible was then placed over a ring and a fine magnesium wire touching the fuel sample was stretched across the two electrodes. The lid was tightly screwed and the bomb was filled with oxygen up to 25 atmosphere pressure. The initial temperature was noted and recorded. The electrodes were then connected to a 6V battery and the circuit was switched on, the fuel in the crucible burnt with the released of heat which was absorbed by the surrounding water inside the bomb calorimeter. This gave rise to a sharp rise in the water temperature and the maximum temperature attained was recorded. The concept of change in temperature and specific heat were then used to calculate the calorific value (Sani *et al;* 2018; Kaisan *et al*., 2013).

Determination of Cetane Number

Cetane number is a function of saponification and iodine values of the corresponding fuel sample, it was determine from the correlation reported by (Ibrahim *et al.,* 2019) in Equation 5.

$$CN = 46.3 + (5458/SV) - 0.225 \times I.V \quad (5)$$

Where; CN is the Cetane number while S.V and I.V are the saponification and iodine values of the fuel under test.

Determination of carbon content

The percentage of carbon content in a biodiesel was determined using ASTM D5291. In this method, 3g of biodiesel sample was weighed as W_0 and placed in a crucible containing 0.4 g of glass bead and weighed as W_2, the glass bead was used to ensure uniform heating. The crucible was placed in the center of the skidmore iron crucible (Stanhope-Set apparatus) and heat was introduced, the pre-ignition period observed was 30 ± 7 min when smoke appeared above the chimney. The experiment lasted for 60 ± 5 min in an air-free environment. After the heating, the test crucible containing the carbonaceous residue was cooled in a desiccator and weighed as W_3. The percentage of carbon residue was calculated using Equation 6 as reported by (Adeyemi *et al*., 2021; Samuel *et al*., 2016).

$$\% \text{ Carbon residue} = \frac{W3-W1}{W0} \times 100\% \quad (6)$$

Where: Mass of biodiesel = W_0,

Mass of glass bead = W_1

Mass of biodiesel+ glass bead = W_2

Mass of carbon residue and bead after evaporation and pyrolysis of the biodiesel = W_3

Mass of carbon residue = $W_3 - W_1$

Determination of Ash content

The percentage of ash content was determined by ASTM D482 method as reported by (Benjamin *et al*., 2023). In the method, a clean and empty crucible was weighed using an electronic weighing balance and denoted as W_0, 3g of the biodiesel sample was placed into the crucible and weighed as W_1. The crucible was then placed inside in an electric muffle furnace and heated at 600^0C for 4h; ash of gray-white color appears, and this suggests that all the organic matter in the biodiesel has been completely oxidized. The crucible was then removed and allowed to cool in a desiccator and then weighed W_2. The percentage ash content was calculated using Equation 7.

$$\% \text{ Ash content} = \frac{\text{difference in weight of Ash}}{\text{weight of sample}} \times 100\% \quad (7)$$

$$= \frac{W2-W0}{W1-w0} \times 100\%$$

Where W_2 = weight of the crucible with ash,

W_0 = weight of the crucible alone,

W_1 = weight of the original sample.

RESULTS AND DISCUSSION

Physico-chemical properties of the biodiesel

Table 1: Experimental properties of biodiesel, diesel and ASTM D6751

S/N	Name of Property	*Lannea microcarpa* biodiesel	Diesel	ASTM D 6751
1	Density (g/cm^3)	0.8965	0.850	0.860-0.900
2	Kinematic viscosity (mm^2/sec)	6.00	2.96	1.9-6.0
3	Saponification value (mgKOH/g)	240.7	-	-
4	Iodine Value (g/100g)	120	-	-
5	Calorific value (MJ/kg)	38.5	45.5	39-43.33
6	Cetane number	41.98	50	46-65
7	Flash Point (°C)	128	75.5	100-170
8	Fire Point (°C)	140	150	110-200
9	Cloud Point (°C)	5.0	2	-3 -15
10	Pour Point (°C)	-9.5	3	-15 – 16
11	Carbon residue (%)	0.50	0.26	0.35
12	Ash content (%)	0.030	0.021	0.01

Density

Density is an important parameter related to the fuel atomization, injection system and it affects the energy content, its value must be maintained within a tolerable limit to allow optimal air to fuel ratios for complete combustion (Ibrahim *et al*., 2021). The density of the biodiesel was 0.8965 as presented in Table 1, this value fell within ASTM range (0.860-0.900). It is slightly greater than that of conventional diesel (0.850); this could be attributed to higher molecular weight of fatty acid components of the biodiesel (Christiana *et al*., 2014). Results from similar studies showed that, the density obtained from this research was in close proximity with 0.88, 0.8645 and 0.890 reported by Yunus *et al.* (2013), Kaisan *et al*., (2013) and Agarry *et al*. (2013), respectively. Generally, higher density causes fuel flow resistance, which may lead to inferior fuel injection, and low-density in fuel can lead to an increase in efficiency of atomization and promotes fuel-air mixture formation that resulted in better combustion characteristics (Yusop *et al.,* 2014). Hence, in terms of density, fuel with low density is preferred over fuel with high density and for the produced biodiesel it has the potential to replace fossil fuel since its density falls within the ASTM range.

Kinematic viscosity

The kinematic viscosity is one of the most critical properties of biodiesel as its value strongly affects the mode of starting an engine, the spray quality, quality of air-fuel mixing and injection behavoiur (Dario *et al*., 2020). It can be observed from Table 1 that, the kinematic viscosity of the biodiesel was found to be 6.0 mm^2/s, it fell within the ASTM specifications (1.9 - 6.0 mm^2/s), and it was relatively higher than that of diesel fuel (2.96 mm^2/s), this could be attributed to the fatty acid components of the biodiesel (Christiana *et al*., 2014). The higher viscosity of biodiesel compared to fossil diesel implies that biodiesel will have more lubricating effect in engines, hence, an added advantage to the users, since it will reduce wear and tear in the engine parts. Results from similar studies showed that, the viscosity (6.0 mm^2/s) of this biodiesel is higher than 3.93 mm^2/s and 4.80 mm^2/s reported by Kaisan *et al*., (2013) and Agarry *et al*, (2013) but lower than 9.20 mm^2/s reported by Sreedhar and Durga, (2015). Viscosity of biodiesel affects the injector and fuel atomization, the higher the viscosity, the larger fuel droplet sizes which in turn result in improper air fuel mixing; and finally leads to poor combustion and high particulate matter emissions. Similarly, when the viscosity is too low, it results to reduction in peak heat release rate, degree of fuel impingement and air fuel mixing rate (Sani *et al*, 2018; Auwal *et al*, 2012). The kinematic viscosity of this biodiesel is within the ASTM specifications; this signifies that this fuel is a potential substitute for diesel fuel anticipated to provide a better engine performance.

Iodine Value

The iodine value (IV) measures the degree of unsaturation in fuel and determines its oxidative stability (Ioan and Barabas, 2011). From table 1, the iodine value for the biodiesel was found to be 120 gI/100g. This value was in close agreement with 117.3 ±0.1 gI /100g of *Glycine max* seed reported by (Lawan *et al*., 2019). Biofuels with an IV above 125 are classified as drying oils; those with an IV of 110–140 are classified as semidrying oils while those with Iodine values less than 110 are considered as nondrying oils (Samir and Rehab, 2015). High Iodine value indicates high unsaturation level of fats and oils, while low value implies high stability of the oils (Yunus and Kyari, 2016). The IV highly depends on the nature and ester composition of the feedstocks used in biodiesel production. The results indicated that, this biodiesel is a semi-drying fuel. Biofuel with high IV tends to polymerise and the tendency of polymerisation increases with the extent of unsaturation of the fatty acids (Samir and Rehab, 2015). The unsaturation in the fatty acid chain is the primary source of thermal instability that causes longer ignition delays by retarding the start of combustion. Consequently, it leads to carbon deposits and soot formation during the operation. However, saturated fatty acids also form crystals during cold weather operations that clog fuel filters and lines, thus causing improper engine operation (Ioan and Barabas, 2011). In this study, the biodiesel has moderate iodine value; therefore, it is has lesser tendency to produce higher carbon deposits on the piston.

Saponification value

Saponification value (SV) is an indicator of the amount of alkali required to convert oil into soap and it is an index of the average molecular mass of fatty acid in the oil sample. The value is simply given as a measure of the milliliters of potassium hydroxide (KOH) required completing the hydrolysis of one gramme of oil. A high SV indicates a higher proportion of low molecular weight fatty acids in the oil or vice versa (Samir and Rehab, 2015). From Table 1, it is observed that, the saponification value for the biodiesel is 240.7mgKOH/g. It is comparable to 291.8 mgKOH/g obtained from Neem oil biodiesel reported by (Yahuza *et al*., 2018). The obtained value is relatively higher than 153.40 ± 2.45 mgKOH/g of *Lannea microcarpa* seed oil reported by (Yunus *et al*., 2013). The high saponification value of the oil and biodiesel indicated its high tendency of soap formation and corrosion problems in the engine parts (Ming *et al.,* 2014). However, it could equally be treated to reduce the saponification value to make it suitable for engine operation.

Cetane number

Cetane number is a measure of the tendency of fuel to self-ignite, a fundamental property in cold starting conditions. It also highlight on the possibility of a fuel to cause engine knock in a diesel engine (Hilton and Freddie, 2021). The cetane number of the biodiesel was found to be 41.98 and this reveals that the value obtained was close to the ASTM limit (46 – 65) and slightly lower than that of conventional diesel (50). Results from similar study showed that, the cetane number (41.98) obtained was in close proximity to 44 obtained from *Lannea microcarpa* biodiesel reported by Kaisan *et al*., (2013). Fuels with a relatively higher cetane number would have better ignition quality, smoother combustion, cleaner exhaust, and easier cold starting than those with lower values (Gabriel *et al.,* 2020). This implies that diesel has better ignition quality than *Lannea microcarpa* biodiesel. However, since the cetane number of this biodiesel is close to ASTM limits, it has the potential for use in CI engines.

Calorific value

Calorific value (CV) is the heat energy released when unit quantity of fuel is completely burnt, and the greater the CV, the higher the energy produced by the fuel (Hilton and Freddie, 2021). According to (Ashraful *et al*., 2014) biodiesel have lower calorific value compared to diesel due to the presence of chemically bounded oxygen; it is the oxygen in the biodiesel resulted to complete combustion in the I.C engine (Ashraful *et al*., 2014). From Table 1, the calorific value of biodiesel was found as 38.50 MJ/kg, it is lower than that of petro-diesel (45.5) and it fell within the ASTM limit

(39 – 43.33). The calorific value of this biodiesel (38.50) is much higher than 10.831MJ/kg obtained from the same feedstock by Kaisan *et al*., (2013), and this reveals that in terms of energy content, the biodiesel produced in this research work is far better than the one reported by Kaisan *et al.*, (2013). Generally, a high calorific value is desirable since it indicates the fuel's energy content. Hence, this makes the biodiesel suitable to replace diesel in CI engine operations.

Flash point

Flash point is defined as the lowest temperature at which the fuel ignites when expose to flame or spark in specific conditions. Flash point is inversely proportional to volatility; high flash point indicates low volatility of fuel and vice-versa (Sani *et al.*, 2018). From Table 1, the flash point for the biodiesel was found to be 128.0 ºC, it fell within the ASTM range (100 – 170 ºC) and it is relatively higher than that of diesel (75.5 ºC). The flash point of this biodiesel is higher than 75 ºC and 58 ºC, reported by Kaisan *et al.* (2013) and Sreedhar and Durga (2015), respectively. A higher flash point is desirable; hence, biodiesel under this study is less flammable compared to diesel. This means that the fire hazard associated with the transportation, storage, and utilization of this biodiesel is less than that of diesel. Therefore, it can be safely stored and transported to various parts of the tropical country with extremely high temperatures (Ashraful *et al*., 2014).

Fire point

The fire point is the lowest temperature at which the vapor of fuel continues to burn for at least 5 seconds after ignition (Omid *et al.*, 2023). From Table 1, the fire point obtained for the biodiesel is 140^0C, it fell within the ASTM range (110 – 200^0C) and it is slightly less than that of diesel fuel (150^0C). The fire point of this biodiesel is relatively higher than 90^0C obtained from the same feedstock by Sreedhar and Durga (2013). A higher fire point is desirable; hence, biodiesel under this study is less flammable compared to the one produced from the same seed oil by Sreedhar and Durga (2013). Furthermore, the flash point of this biodiesel is in close proximity to that of fossil diesel but however diesel is less volatile than *L. microcarpa* biodiesel. This means that the fire hazard associated with transportation, storage and utilization of fossil diesel is less than that of *L. microcarpa* biodiesel.

Cloud point

The cloud point is the temperature at which fuel begins to form wax crystals when it is cooled; it is commonly used to measure low-temperature operability of the fuel (Adeyemi *et al*., 2021). As depicted from Table 1, the biodiesel had a cloud point value of 5^0 C, it fell within the ASTM specifications (-3 – 15^0 C). It is relatively higher than that of diesel (2^0C) and this agrees with the findings from (Ioan and Barabas, 2011). It is also higher than -5^0C derived from the same feedstock by Kaisan *et al*., (2013). In Nigeria, the average room temperature (ambient temperature) is above 20°C (Kaisan *et al.*, 2013); this implies that the biodiesel in the present study could be used in a cold weather region of Nigeria without blocking the fuel system. At temperature below the cloud point larger crystals would fuse together and form agglomeration that finally make it difficult in pouring of the fluid; the crystals might plug fuel lines and filters or fall to the bottom of the storage tank, these can result to engine failures (Adeyemi *et al.*, 2021).

Pour point

The temperature at which wax is first seen in the fuel is the cloud point of that fuel, while the temperature at which the fuel solidifies and will no longer flow is the pour point. At this temperature the biodiesel cannot be pumped (Adeyemi *et al*., 2021 ; Sani *et al*., 2018). The pour point for the biodiesel was found to be -9.5^0C, it fell within ASTM specifications (-15-16) and lower than that of diesel (3^0C). Results from similar studies showed that this value is relatively higher than -10^0C and -22^0C reported by Sreedhar and Durga (2015) and Agarry *et al*., (2013), respectively. According to (Kaisan *et al.*, 2013), the average room temperature (ambient temperature) is above 20°C in Nigeria, hence, this biodiesel considered in this research can pour well in this Nigerian wheather.

Carbon residue

Carbon residue is an indication of carbon depositing tendencies of the fuel. It has high correlation with the presence of free fatty acid, glycerin, soaps, polymers and other impurities (Surma *et al*., 2024; Adebayo *et al*., 2021). From Table 1, the value of carbon residue obtained for the biodiesel is 0.5%. This value is relatively higher than that of diesel fuel (0.26%) and the ASTM limit that is 0.35 wt.% max (Ioan and Barabas, 2011). This implies that biodiesel will form more carbon deposits in engine than diesel fuel.

Ash content

Ash content of biodiesel is an indication of the presence of inorganic matter, catalyst residues and other impurities in the fuel (Yunus and Kyari, 2016; Adebayo *et al.*, 2021). From the result in Table 1, the ash content of the biodiesel was 0.03%, this value is close to prescribed ASTM limit (0.01 wt.% max) and that of diesel fuel (0.021%). The result is contrary to the findings of (Anuraja and Manohar, 2014), who reported that ester and its blends had an ash content less than that of diesel. This showed that biodiesel would produce more ash when burnt than diesel fuel. High concentration of ash materials in fuels could lead to injector tip plugging, combustion deposits and injection system wear. While, the low ash value is a signal that the oil lacks trace metals that catalyze oxidation reactions which cause rancidity, high acidity and other unpleasant characteristics during storage (Yunus and Kyari, 2016; Samuel *et al*., 2016). In terms of ash content the biodiesel is a good potential since the obtained value is close to ASTM and that of conventional diesel.

CONCLUSION

From the experimental result it could be concluded that, the percentage of the *Lannea microcarpa* seed oil and the biodiesel yield were found to be 46.15% and 90.63% respectively. This feedstock was highly enough to be classified as economically viable source for biodiesel production. The results revealed that all 12 assessed properties nearly conform to ASTM D6751 standard. It was noted that, the density, viscosity, cetane number, calorific value, ash content and carbon residue of fossil diesel were found to be slightly better than those of the biodiesel. Conversely, the biodiesel exhibited slightly better cloud point, pour point, flash point, and fire point than fossil diesel. Therefore blending of the two fuels could improve their physico-chemical properties. It could be concluded from this study that the biodiesel produced from *Lannea microcarpa* seed oil is a potential replacement for fossil diesel while the production and effective utilization of the biodiesel will help to reduce the cost of fossil diesel and its environmental impacts, and hence will boost the economy of the country.

REFERENCES

Adebayo F and Weng F. (2021):A Study on Performance Evaluation of Biodiesel from Grape Seed Oil and Its Blends for Diesel Vehicles. *Vehicles*. 3: 790–806.

Adeyemi D.T; Saleh A; Akande F.B; Oniya O.O; Ola F.A (2021): Determination of Fuel Properties of Biodiesel from Sand Apple Seed Oil with Automotive Gas Oil Blend, *J. Appl. Sci. Environ. Manage.* 25 (8): 1365-1369.

Adhikesavan C, Rajagopal K and Selwin R.J (2015): Production and characterization of biodiesel from *Acacia nilotica* seeds, *International Journal of ChemTech Research*, ISSN: 0974-4290. 8(2): 854-859.

Awulu J.O., Ogbeh G.O., and Asawa N.D., (2015): Comparative Analysis of Biodiesels from Calabash and Rubber Seeds Oils, *Int. Journal of Renewable Energy Development* 4(2): 131-136.

Ashraful, A.M., Masjuki, H.H., Kalam, M.A., Fattah, I.R., Imtenan, S., Shahir, S.A., Mobarak, H.M., (2014) "Production and comparison of fuel properties, engine performance, and emission characteristics of biodiesel from various non-edible vegetable oils: a review". *Energ. Conserv. Manage*. 80: 202–228.

Anuraja B. and Manohar J.D.(2014). A studies on Physico-chemical Properties of *Jatropha* biodiesel blends, *Plant Archives.* 14 (2):1005-1009.

Agarry, S.E., Aremu, M.O., Ajani, A.O., and Aworanti, O.A. (2013): Alkali – catalysed production of biodiesel fuel from Nigerian Citrus seeds oil. *International Journal of Engineering Science and Technology (IJEST).* 5 (9): 1682-1687.

Auwal, A. Oche, A. and Abdulhamid H. (2012): Binary blends of petrodiesel with biodiesels derived from soyabean and groundnut oils. *Journal of Advances in Applied Science Research.* 3(1): 611-614.

Benjamin O. E., Kingsley O. O., Juliet N. O., Alfred F., Sabinus O.O. E. (2023): Biodiesel potential of *Cucumeropsis mannii* (white melon) seed oil: A neglected and underutilized resource in Nigeria. *Heliyon* 9: 1-13.

Christiana C . E., Vincent A., and Clementina C.(2014): Comparative Analysis of the Physico-chemical Properties of Oil from *Cucumis melossp. agrestis* (Wild melon) Seeds, its Biodiesel, Biodiesel Blend and Petro- diesel. *International Journal of Pure & Applied Bioscience*, 2 (1): 286-293.

Dario Al., Guillermo A., Thomas D., (2020): Prediction of biodiesel physico-chemical properties from its fatty acid composition using genetic programming. *Fuel* 264 (116844): 1-12.

Gabriel, R., Vieira, W.T Soletti J.I Ribeiro L.M.O and Carvalho S.H.V (2020): Empirical modelling of different viscosity and density behaviour of biodiesel from *chichá (Sterculia striata)* with diesel versus temperature variation, *Journal of King Saud University* - Science 32(1):628-635.

Hilton M and Freddie L.I (2021): A Review on waste cooking oil biodiesel as a viable fuel for diesel engines: Existing concepts, emerging trends and future prospects. *International Journal of Mechanical and Production Engineering Research and Development (*IJMPERD). 11(5): 11–32.

Ibrahim Y, Abba M. M & Surajo A (2021): In-situ-transesterification of Cotton seeds Oil (Gossypium spp) using Cao Derived from Egg shell as Catalyst. *Journal of Agriculture and Veterinary Sciences.* 13 (1): 1-13.

Ibrahim, M. H. Dasin D. Y and Yahuza I. (2019): The Physicochemical Analysis of Biodiesel Produced from African Sweet Orange (*Citrus Sinensis*) Seeds Oil, International Journal of Engineering Technologies and Management Research, 6(6): 82-91. https://doi.10.29121/ijetmr.v6.i6.2019.396.

Ioan, A and Barabas, I. T (2011): Biodiesel Quality, Standards and Properties, (5th Ed.) InTech, ISBN: 978-953-307-784-0., Pp 1-28.

James Y, Dogara K and Rhoda O. M. (2021): Studies on *Cucurbita maxima* Seed Oil for its Potentials as Feedstock for Biodiesel Production in Nigeria. *Nigerian Research Journal of Chemical Sciences.* 9 (1):215-233.

Kaisan M.U, Anafi F. O. , Umaru S , .Kulla D. M. and Nuszkowski J (2017): Fuel Properties of Biodiesel from Neem, Cotton and Jatropha Binary and Multi-blends with Diesel, *Nigerian Journal of Materials Science and Engineering.* 7 (1): 59-66.

Kaisan M.U, Pam G.Y., and Kulla D.M., (2013). Physico-Chemical Properties of Bio-diesel from Wild Grape Seeds Oil and Petro-Diesel Blends. *American Journal of Engineering Research (AJER).* 2(10): 11-21.

Lawan, M. M. and Serder, S. (2019): Analysis and Characterization of Biodiesel Production from *Glycine max* seed Oil using Alkali catalyst. *FUDMA Journal of Sciences (FJS).* 3 (1): 84 – 90.

Maulidiyah, Muhammad N, Fetty F, Muh N, Dwiprayogo W (2017): Characterization of methyl ester compound of biodiesel from industrial liquid waste of crude palm oil processing. *Analytical Chemistry Research*, 12: 1-9.

Mofijur M, Rasul M.G, Hyde J, Azad A.K, Mamat R. Bhuiya M.M.K, (2016): Role of biofuel and their binary (diesel–biodiesel) and ternary (ethanol–biodiesel–diesel) blends on internal combustion engines emission reduction. *Renewable and Sustainable Energy Reviews*, 53: 265–278.

Ming C, Qingshi T, Mingming L, and Jeffrey Y (2014): Esterification pretreatment of free fatty acid in biodiesel production, from laboratory to industry. *Journal of Fuel Processing Technology, Elsevier*, 125:106-113.

Musa, U., Mohammed I .A., Sadiq M.M., Aliyu A.M, Suleiman B., and Talabi S. (2014): Production and Characterization of Biodiesel from Nigerian Mango Seed Oil. Proceedings of the World Congress on Engineering, 2014 Vol I, WCE 2014, July 2 - 4, 2014, London, U.K.

Nurun, N., Mostafizur, R., Muhammaad, A.I., Farhad, M.H., Peter, B., William, N.R., John,T., Zoran, D.R., Richard, J.B., (2015). Fuel characterization, engine performance, combustion and exhaust emissions with a new renewable

Licella biofuel. *Energy Conversion and Management.* 96: 588–598.

Nafiu, T., Zuru, A.A., Kaisan, M.U., Ummi, I.M., and Yusuf, B.H. (2011): Production of Biodiesel from Wild Grapes (*Lannea Microcarpa*) Seeds" *Nigerian Society of Engineers Technical Transaction Journals,* .6(1): 1-15.

Omid K., Alireza P., Mohammad A. Z., Abozar S., Zahra S. Z., Amin M. (2023): Biodiesel-Petrodiesel Blends Physicochemical Characterization and Economic Assessment of Designing a Plant in Iran. *Journal of Environmental health and sustainable development (JEHSD),*8: 1, 1897-18914.

Oliveira L. E., 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*. 11: 1-4.

Surma N, Ijuo G. A, Nyom P. N, Ukpoko E, Kutshaq P.I (2024): Comparative Study of Physico-Chemical Properties from Roosted and Refined Palm Kernel Methylester. *International Journal of Advanced Research in Chemical Science* (IJARCS). 11(1): 18-24.

Suleiman, K. K., Isah, M., Abdulfatai, A. S., Danyaro, Z. (2023): Kinetics and Thermodynamics Study of Biodiesel Production from Neem Oil using Alumina as a Catalyst, *FUDMA Journal of Sciences (FJS)*. 7 (3): 65-71.

Sani S., Kaisan M.U., Kulla D.M., Obi A.I., Jibrin A., Ashok A.B. (2018) :Determination of physico-chemical properties of biodiesel from Citrullus lanatus seeds oil and diesel blends. *Industrial Crops & Products* 122: 702–708.

Sadiq A. S (2016): Assessment of Nigeria sweet orange seed oil for biodiesel production. *Nigerian Journal of Tropical Engineering*, 9 (1 & 2) :1-9.

Samuel E.O., Sunny E.I., Anselm I.I., Diakanua B. N. (2016): Rubber seed oil: A potential renewable source of biodiesel for sustainable development in sub-Saharan Africa. *Energy Conversion and Management.* 110:125–134.

Samir A. A.I. and Rehab F. M. Al (2015): Physico-chemical properties of biodiesel manufactured from waste frying oil using domestic adsorbents. *Science and Technology of Advanced Materials*, 16: 1-9.

Sreedhar C, Durga B.P, (2015) "Performance Evaluation of Four - Stroke Single Cylinder DI Diesel Engine Using Different Blends of Diesel and Grape Seed Biodiesel". *International Journal of Engineering and Innovative Technology (IJEIT).* 4(11): 255-261.

Yahuza I., Farinwata s.s, Dandakouta H, Dasin D.Y (2018): Production and Characterization of Biodiesel-Ethanol-Diesel Blend as Fuel in Compression-Ignition Engine , *IJSRSET* . (4)1: 1415-1424.

Yunus M. M. and Kyari M. Z (2016): Quality Assessment of Biodiesels from *Lophira Lanceolata* and *Ziziphus Mauritiana* Seed Oils. *Nigerian Journal of Chemical Research.* 21: 12-22.

Yusop, A., Mamat R., Yasin M.M and Ali O.M (2014): Effects of particulate matter emissions of diesel engine using diesel–methanol blends. *Journal of Mechanical Engineering and Sciences* 6: 959-967.

Yunus M.M, Zuru A.A, Faruq U.Z and Aliero A.A (2013): Assessment of Physico-chemical Properties of Biodiesel from African Grapes (*Lannea microcarpa). Nigerian Journal of Basic and Applied Science.* 21(2): 127-130.