



Production and Characterization of Hybrid from Feedstock of Moringa Oleifera and Palm Kernel Seeds Oil

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ABSTRACT

The study examined the production and characterization oil from moringa oleifera and palm kernel seeds. The moringa oleifera and palm kernel seeds oil were extracted Soxhlet extractor. The seeds oil feedstock was converted to biodiesel through in-situ hybridization process, at different blend ratios. Moringa oleifera biodiesel feedstock was used as the main constituents in the in situ hybridization and as such the maximum allowable ratio of ≤ 50 for excellent biodiesel qualities was adopted. The hybridized blends adopted for this study are MB80PKB20, MB50PKB50, MB30PKB70. The hybridized biodiesel fuel blends were characterized using ASTM D6751 and EN 14214 standards. Characterization of the hybridized biodiesel fuels blends conform to the stipulated standards with the exception of acid number. The acid number for the pure biodiesel feedstock and that of the hybridized blends were all above the stipulated limit of 0.5. Moreover, hybridized blend of MB30PKB70 possess high pour point which falls above the acceptable maximum range of 195 – 261 mgKOH/g. From the foregoing, it could be deduced that the hybridized biodiesel blends could be used in compression ignition engines.

ARTICLE INFO

Article History

Received: June, 2023

Received in revised form: September, 2023

Accepted: December, 2023

Published online: March, 2024

KEYWORDS

Moringa oleifera, Palm kernel, seed oil,
Biodiesel, Fuels, Hybridization, ASTM.

INTRODUCTION

Energy has been described as the lifeblood of a nation. A nation that cannot process and supply what it needs, in terms of energy supply, is bound to be experienced energy deficit. Looking at the global strategic distribution of energy reserves from conventional sources, it is quite apparent that demand and supply of these resources could not be the same across the entire globe. In addition to the distribution network, the reserve of these resources have been declared as being finite. Therefore, as a result of exponential growth in population across the world couple with advancement in technology, a corresponding increase in demand due consumption of energy by human activity is inevitable (Zubairu and Ibrahim, 2014). Hence, existing sources needs to be manage and part of the strategies involved are to seek for alternative sources, which are

replenished within a short period of time as compared to conventional sources.

Alternative energy sources are those sources that can continuously replenish by natural processes be used to produce energy again and again, i.e. it can be renewed within a short time. These includes: solar, wind, bio-mass (or bio-feed stock), geothermal, tidal and hydro.

Biofuel refers to solid, liquid, or gaseous fuels which are made from bio-renewable feed stocks (Demirbas, 2009). The natural and renewable domestic fuel generally termed biofuel is considered as a promising and economical alternative and likewise a sustainable energy source. Biofuel is a fuel produced from any renewable biomass material. It is commonly used as an alternative, cleaner fuel source to burning fossil fuels (Demirbas, 2008). Biofuel can be produced from various materials which are in contrast with conventional diesel that can be

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produced from only a specific type of material (Vera and Langlois, 2007). Liquid biofuel is a type of biofuel which is essentially employed in fuelling vehicles and sometimes engines (Vera and Langlois, 2007).

Biodiesel fuel has become more attractive because of its environmental benefits (Demirbas, 2003). Compared to petroleum diesel, biodiesel has lower emission of pollutants, it is biodegradable and enhances the engine lubricity and also contributes to sustainability (Kurki, 2006). Biodiesel has a higher cetane number than diesel fuel, no aromatics, low sulphur, and contains 10–11% oxygen by weight (Conakci, 2007). The properties of biodiesel are comparable to ordinary diesel fuel with enhanced lubricity properties (Ylmaz, 2014) and reduced pollutant emissions (Franco et al., 2013).

Hence the focus of the research work is to generate multi blend biodiesel from two different seed oils: moringa and palm kernel seeds esterification process. The derived biodiesels was blended with conventional diesel in different ratios to obtain the optimum blends and the physicochemical properties of the multi blend biodiesel was evaluated using appropriate methods

LITERATURE REVIEW

Numerous articles which have significantly contributes to the propagation on the meaningful achievement and use of have been published (Demirba, 2003; Soni, 2011; Alnuami et al., 2014; Sanjid et al., 2014; Ali et al., 2015; Yasin et al., 2017 and Zahan and Kano 2018) employing different variety of seeds. Omonhinmin et al.,(2020) conducted a review on the extend of extraction of Moringa Oleifera oil and its subsequent conversion and utilization as a feed for biodiesel production. The reviewed document revealed that thephysicochemical properties of Moringa biodiesel meets EN 14214 and ASTM D6751 international standard with great potentials to curtail greenhouse gases and promote sustainable energy supply. Bong et al., (2018) conducted a research on the synthesis and characterization of biodiesel from Cameroon Palm Kernel Seed Oil employing esterification process

in methanol with potassium hydroxide as base in ratio of 100:20:1. The synthesized biodiesel obtained was optimized and the yield obtained was about 97%. In addition, the results of the physico-chemical properties were found to be in close agreement with those of diesel. Eze(2012) investigated the feasibility of using twelve (12) selected tropical seeds as sources of biodiesel production, according their yields. The physico-chemical analysis revealed that tested parameters were within the American Society for Testing and Materials. Hence, the present examined the production and characterization of Moringa Oleifera and palm kernel seeds oil with the view of hybridizing the two at different blend ratio to obtain a higher-grade biodiesel fuel.

METHODOLOGY

Sample Preparation

Production of Moringa and Palm-kernel Seed Oil

1000g of each of the dried seeds were de-husked and crushed using commercial grinder. The crushed seeds were in-turn fed to the Soxhlet extractor fitted with the 2 litre round bottom flask. 100g of each of the powder was poured into the thimble of the Soxhlet apparatus with 210ml of ethanol in the Soxhlet apparatus. The thimble is well porous such that the solvent can percolate through the extracted oil at the extraction temperature. The top of the Soxhlet was covered with a condenser which condenses the solvent back to liquid state before returning it back to the round bottom flask. The extraction was executed on a water bath for 6 h with n-hexane. The solvent was removed under vacuum using a rotary evaporator. The oil obtained was then weighed after drying in an oven for 3 hours at 80°C to remove any solvent present. The oil is then weighed and the weight of the oil was divided by the weight of the seed containing oil, then the result was multiplied by 100 to get oil yield in %. The amount of oil extracted was determined using the equation:

Percentage Oil Content (%)

$$\text{Oil Content (\%)} = \frac{\text{Weight of oil extracted}}{\text{Weight of seed}} \times 100 \quad (1)$$

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PRODUCTION OF MORINGA AND PALM-KERNEL SEED OIL BIODIESEL

Preparation of Sodium methoxide

Thirty millilitres (30mL) of methanol was measured into a 250mL flat bottom flask and covered immediately. 1.06 g of potassium hydroxide was carefully added into a methanol to make a solution which was made air-tight. It was shaken and swirled for a few times until the KOH was completely dissolved.

Esterification Process

1% of H₂SO₄ (Sulphuric acid) was added with 30 ml of methanol into a conical flask containing 100 ml of the oil sample. The mixture was stirred vigorously for 30 minutes using a magnetic stirrer. Then poured into a separating funnel and allowed to separate for about 10 hours. The impurities formed a top layer while he treated oil formed a layer below and was collected in a beaker and oven dried for 1 hour at 105°C to remove the excess methanol.

Biodiesel production (Transesterification)

The trans-esterification reaction was carried out in a 500 ml air-tight flat bottom flask on a magnetic stirrer. The 100 ml of the sample oil was measured into the flask and was heated to a temperature of 55°C. The Sodium methoxide was then poured into the flask containing the oil and was immediately covered. The temperature of the system was maintained between 60-65°C throughout the one hour reaction time. At the end of the reaction, the mixture was transferred into a separating funnel, left for 24 hours and the biodiesel was then washed with warm water four times to a neutral pH to remove the soap formed due to saponification reaction caused by the Sodium methoxide catalyst and other impurities. The water was allowed to settle down before removing it by draining. The washed biodiesel was collected into a beaker and gently heated in an oven at 105°C to evaporate the excess water and methanol in the biodiesel. The biodiesel and its blend were analysed in the same way as the oil for their physicochemical parameters.

The volume of the purified biodiesel produced was measured using measuring cylinder and the biodiesel yield (wt %), relative to the amount of each oil was calculated.

$$\text{Biodiesel Yield (\%)} = \frac{\text{Volume of Biodiesel Recovered}}{\text{Volume of oil used}} \times 100 \dots\dots\dots (2)$$

Preparation of Palm Kernel and Moringa Biodiesel Blends

Biodiesel from palm kernel oil and moringa seed was first blended at 70:30, 50:50 and 20:80. The best sample was blended with conventional diesel at a proportion of B10, B20, B30 and B40 in other to get the best blend for optimum physiochemical properties and engine performance. 70 ml of biodiesel from palm kernel seed was measured in a cylinder and poured in a beaker, 30 ml of moringa seed biodiesel was added and the mixture was continuously stirred to form a 70:30 blend. Similar blends were further made with 50 ml for each of moringa biodiesel as well as palm-kernel oil biodiesel to form a ratio of (50:50) as well as 20 ml palm kernel seed biodiesel with 80 ml moringa seed biodiesel to form a ratio of (20:80)

Characterization of Biodiesel Blends

ASTM standard fuel tests was conducted on the various biodiesel produced to determine their Specific gravity, kinematic viscosity, cloud point, pour point, flash point, fire point, free fatty acid value, saponification value, iodine value and their acid value.

Determination of Specific Gravity

1. 50 ml pyrometer bottle was washed, dried and weighed.
2. The bottle was filled with water and weighed.
3. The bottle was emptied, dried and filled with the extracted biodiesel and palm kernel oil and also weighed.

$$\text{Specific Gravity} = \frac{\text{weight of 50 ml of oil (biodiesel)}}{\text{Weight of 50 ml of water}} \dots\dots\dots (3)$$

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DETERMINATION OF DENSITY

The densities of the samples were determined by ASTM method D-129:

1. The samples were brought to a specified temperature and a test portion was transferred to a hydrometer cylinder that has been brought to approximately the same temperature.
2. The approximate hydrometer, also with a similar temperature was lowered into the test portion and allowed to settle.
3. After equilibrium temperature has been reached, the hydrometer scale reading and the temperature of the test portion were taken.
4. The observed hydrometer reading was reduced to the reference temperature by means of a petroleum measurement table.
5. The hydrometer scale reading was recorded to the nearest 0.1 kg/m³ as the density.

DYNAMIC AND KINEMATIC VISCOSITY

The viscosity of the oil was determined using the Brook field Digital rotational viscometer.

1. The sample was heated in the hot oil bath and the spindle of the viscometer was fitted into the melted wax.
2. The speed was selected and the start button was pressed for the spindle to rotate and give the angle of rotation including the viscosity measurement and the operating temperature on the display.

The kinematic viscosity is the ratio of dynamic viscosity to the density.

$$\text{Kinematic Viscosity} = \frac{\text{Dynamic Viscosity}}{\text{Density}} \dots\dots\dots (4)$$

Determination of Iodine Value

1. 0.2 grams of test sample was weighed into a 500 ml conical flask and 10 ml of chloroform was added to the oil.
2. 10 ml of hanus solution was added and allowed to stand in the dark for 1 hour.

3. 10 ml of 10% potassium iodide with 100 ml of water were added and the resulting mixture was then titrated with 0.1 N Sodium thiosuphate solution using starch (0.5%) as indicator.

$$\text{Iodine value} = \frac{(V_1 - V_0) \times T \times 1269}{w} \dots\dots\dots (5)$$

Where:

- V₁ = titre value of blank
- V₀ = titre value of sample
- 1269 = concentration conversion coefficient
- W = weight of sample (g)

Determination of Pour Point

1. 5ml of the sample was drawn into a capillary tube tied to a thermometer and placed in a 250ml beaker containing distilled water immersed together in a water bath for controlled heating.
2. The temperature at which the oil just begins to move downward due to its weight is called the pour point.

Determination of flash point

The flash point was determined using a small strong heat resistance glass cup and a heating mantle.

1. The sample was poured into the cup and heated gradually while being stirred to distribute heat uniformly in the cup and the temperature was monitored using a thermometer.
2. At regular interval temperatures, the cup was exposed to naked flame, the temperature at which the biodiesel increases the flame like a flash but does not increase combustion was recorded, which was the flash point of the sample.

Determination of Higher Heating Value

1. A weighed sample of approximately 0.1 gram was placed inside the calibrated adiabatic bomb calorimeter with 1 millilitre of deionized water. A Chromel (chromium nickel alloy) wire was

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- connected to the two electrodes in the pressure vessel (bomb) and placed in contact with the sample.
- The bomb was then assembled, sealed and purged twice by pressurizing to 0.5 MPa with pure (99.99%) oxygen after which it was vented. Which was later pressurized with pure Oxygen to 2.0 MPa for the test and placed inside a bath containing 2 litres of water in an insulated jacket.
 - A motorized stirrer was placed inside the water bath to circulate the water around the bomb, creating a uniform temperature.
 - The sample was then ignited by passing an electric current through the chromel wire causing the sample to burn to completion in the high pressure oxygen.
 - The bomb and the bucket were then held in a calorimeter jacket that serves as a thermal shield. The result was displayed in the display unit in (MJ/Kg) or (Cal/g). This procedure was repeated for other samples.

Determination of Saponification Value

- 2 g of the sample was weighed into a conical flask and mixed with 25 ml of alcoholic KOH in a similar flask.
- Reflux condensers were fixed to both flasks and the contents were heated in a water bath for one hour, swirling the flask from time to time.
- The flask was then permitted to cool a little and the condenser washed down with a little distilled water.
- The abundance KOH was titrated with 0.5 N HCl acid utilizing phenolphthalein as a pointer. The saponification value was calculated using the equation:

$$\text{Saponification Value} = \frac{(a-c) \times F \times 56.1}{\text{weight of the sample}} \dots\dots (6)$$

Where, b = titre value of blank (ml), a = titre value of sample (ml), F = factor of 0.5 N HCl = 1(in this

case) and 28.05 = mg of KOH equivalent to 1 ml of 0.5 N HCl .

$$\text{Iodine Value} = m \frac{12.69 \times V_2 - V_1 \times \text{Normality of the Titrant}}{\text{weight of the sample}} \dots\dots\dots (7)$$

Where the molecular weight of Iodine is 126.9g.mol and 12.69 is the conversion factor from sodium thiosulphate of iodine.

Determination of Acid Value and Free Fatty Acid

- Ethanol was heated on a water bath for a few minutes to remove dissolved gases.
- The boiled ethanol was counteracted by adding a few drops of phenolphthalein and about 10 ml, 0.1 N potassium hydroxide until a pale pink colour was obtained.
- 2 g of oil was weighed into a 250 ml conical flask and 50 ml of hot previously neutralized ethanol was added.
- The mixture was then carried to a boiler on a water bath and the hot mixture was titrated with 0.1 N potassium hydroxide solution until the pink colour returned.

The acid value was determined from the relation shown in the equation below.

$$\text{Acid Value (mg KOH/g)} = \frac{V \times N \times 56.1}{W} \dots\dots\dots (8)$$

$$\text{Free Fatty Acid} = \frac{\text{Acid Value}}{2} \dots\dots\dots (9)$$

Where, V is the titre value (ml), N is the normality of KOH = 0.1N and 56.1= molar mass of KOH and W is the weight of sample.

RESULTS

Results of Characterization of Moringa and Palm kernel Seeds Oil

Results of the physicochemical properties of the crude selected oils were presented in table 1.

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Table 1: Characterization of Crude Moringa and Palm kernel Seeds Oil

PARAMETER	UNIT	MORINGA OIL	PALM KERNEL SEED OIL
Yield	%	27.42	44.70
Density	g/cm ³	0.9294	0.8990
Specific Gravity		0.95503	0.9192
Kinematic Viscosity	Nm ² /s	3.901	4.110
Acid Value	mgKOH/g	2.3001	2.6928
Free Fatty Acid	mgKOH/g	1.15005	1.3464
Saponification Value	mg/g	197.472	301.818
Peroxide Value	Meq O ₂ /kg Oil	12.0	14.0
Iodine Value	gl ₂ /100g	87.05534	14.9742
Refractive Index		1.463	1.453

The percentage oil yields from the Moringa Oleifera (MOO) and palm kernel (PKO) seeds were resolved at 27.42% and 44.70% respectively. The obtained from PKO was similar to the similar to those obtained by (Eze, 2012). However, the yield from MOO was found to be below those reported by Adegbe et al., (2016) and Oyinade and Damilere, (2020) 38% and 34.4% respectively. Whereas the international standard figures ranges from of 38 – 40% (Adegbe et al., 2016). Furthermore, results reported by Niju et al., (2019), presents the yield obtained from MOO, by employing different extraction temperature, was 10.18% which is less than the international standard. Although, from literatures, 45% yield was obtained by Rekha and Rose (2016) whereas 74% yield could be achieved by deploying enzymes to enhance the recovery of oil from the seed.

The density two oil samples were 0.9294 and 0.8990 for MOO PKO respectively. Although, the values were found to be slightly higher than those found in literature 0.875, 0.922 and 0.879, 0.813 for MOO and PKO as reported by (Azad et al., 2018 and Ishola et al., 2020). Variation in density of oils could be attributed to fatty acid composition and the methods/conditions involved during the analysis (Niju et al., 2019). Acid values obtained for MOO and PKO were 2.3001 and 2.6928 mgKOH/g, respectively. The values fell below the maximum acceptable level of 4 mgKOH/g(CODEX, 2009). The results were found to be in agreement with those compiled by (Eze, 2012). The result of the acid value is an indication of the fatty acid content due to

enzymatic activities which at the long run represent the level spoilage.

Saponification values of MOO and PKO were evaluated at 197.472 and 301.818 mgKOH/g, respectively. The saponification value for the MOO was found to be within the acceptable maximum range of 195 – 261 mgKOH/g (Eze, 2012), while that of PKO was found to be higher than the maximum acceptable level. Reports from the literatures shows that saponification value of oil is inversely related to the average molecular weight of the fatty acid (Eze, 2012). Therefore, the more alkaline may be required to neutralize the available free fatty acid liberated by the oil (Eze, 2012). From table 1, the free fatty acid obtained were 1.5005 and 1.3464 mgKOH/g. However, the maximum allowable content ranges from 5.78 - 7.28 mgKOH/g (CODEX, 2009). Hence, the saponification results obtained is a clear indication that the oils could be used to generate biodiesel. From table 1, the maximum international standard of iodine values for oil ranges between 80 – 106 gl₂/100g.

Interestingly, the selected oils have iodine values below the maximum acceptable, as shown in table 1, which indicates the level of saturation. And this level of saturation is likely to be associated with its stability as reported by (Karmakar et al., 2010). While the peroxide value of MOO and PKO were found to be 20% and 40% respectively, higher than the maximum allowable standard of 10 meg/k (CODEX, 2009). High level of peroxide values indicates high level of oxidative and lipolytic activities, which results in the deterioration of the oil. Hence, antioxidant may

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need to be used to reduce rancidity (Eze, 2012). The refractive index obtained (table 1), is in conformity with international standard which ranges between 1.476 – 1.479 (ASTM, 2002). The values of MOO and PKO obtained also were similar to those reported by Eze, (2012) and Niju et al., (2019).

Results of Hybridization of biofuel feedstock

Hybridization of bio-feedstock implies the co-mingling of two more oils of different sources in varying proportions to produce fuel feedstock of higher quality than the parent source [A, B]. In addition, the process blending crude oil feedstock's, prior to production of biodiesel, in the right proportion is simply referred to as *in-situ* process. Therefore, the moringa oleifera and palm

kernel seeds oil were subjected to *in-situ* hybridization process at different percentage blend composition labelled as: MB₁₀₀, PKB₁₀₀, MB₈₀PKB₂₀, MB₅₀PKB₅₀, MB₃₀PKB₇₀ before transesterification process to biodiesel. The initials MB and PKB stands for moringa biodiesel and palm kernel biodiesel, respectively. While the subscripts for the initials represents the percentage proportion of the individual biodiesel in the blend, as presented in table 2.

It is pertinent to note that hybridization of biodiesel feedstock using moringa as the main constituent was limited to 50%. This is due to moringa excellent biodiesel qualities at maximum ratio of 50 or less [A]. All the hybrid biodiesel fuels were characterized using ASTM D6751 and EN 14214 standards (ASTM, 2002)

Table 2: Physicochemical Properties of Pure Moringa biodiesel, Palm Kernel Biodiesel and the Hybrid Biodiesel Fuels

PROPERTIES	UNIT	MB ₁₀₀	PKB ₁₀₀	MB ₈₀ PKB ₂₀	MB ₅₀ PKB ₅₀	MB ₃₀ PKB ₇₀
Yield	%	97.6	93.3	-	-	-
Density	g/cm ³	0.874	0.898	0.878	0.882	0.889
Specific Gravity	-	0.894	0.918	0.989	0.902	0.909
Kinematic Viscosity	mm ² /s	3.67	4.29	3.86	4.07	3.93
Acid Value	mgKOH/g	2.14	1.823	1.823	1.459	1.346
Free Fatty Acid	mgKOH/g	1.052	0.63	0.912	0.729	0.673
Saponification Value	mg/g	206.448	300.696	210.936	252.450	286.110
Pour Point	°C	4.37	2.22	3.90	3.25	2.84
Cloud Point	°C	6.20	3.1	5.3	4.7	4.1
Flash Point	°C	128	156	132.7	137.4	153.1
Calorific Value	MJ/kg	42.841	38.27	41.076	39.998	41.254
Sulphur	%	0.02	0.05	0.02	0.002	0.03

Influence of hybridization on fuel properties

Table 2, provides the results of analysis for pure moringa and palm kernel biodiesel and that of the hybrid biodiesel fuels from crude moringa oleifera and palm kernel seeds oil. From table 2, it could be observed that the density of pure moringa and palm kernel biodiesel (MB₁₀₀ and PKB₁₀₀) and that of their blends of MB₈₀PKB₂₀, MB₅₀PKB₅₀, MB₃₀PKB₇₀ were evaluated at 0.874 gcm⁻³, 0.898 gcm⁻³, 0.878 gcm⁻³, 0.882 gcm⁻³, and 0.889gcm⁻³ respectively with a recommended range of 0.860-0.900 gcm⁻³EN standard (ASTM, 2002) . While the values of the specific gravity obtained for the same samples were 0.894, 0.918,

0.989, 0.902 and 0.909 respectively. It is pertinent to note that the specific gravity of MB₈₀PKB₂₀ is higher than that of the pure biodiesels, whereas the blends of MB₈₀PKB₂₀, MB₅₀PKB₅₀ tend to be a little higher lower than that of MB₁₀₀ and PKB₁₀₀, respectively. The variation could be as a result of moisture content in the blends. Density is a key fuel property which directly affects the engine performance characteristics with respect to volumetric fuel economy and maximum power.

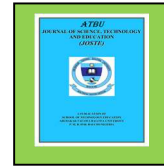
The values of kinematic viscosities of pure moringa and kernel biodiesels and their blends presented in table 2, are within the recommended limits of biodiesel i.e 1.9 -6.0 mm/s²

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(ASTM, 2002). The figures representing the hybrid blends were all found to be better than those of the crude oil. In addition, all values obtained hybrid biodiesel fuels were found to be within the acceptable level of 2.0 – 4.5 mm/s² for conventional diesel fuels (Omonhinmin et al., 2020). Hence, the hybrid biodiesel fuels stand better chance of injection during intake stroke, because easy atomization of the hybrid biodiesel could be achieved which in the long run will promote complete combustion and enhance efficiency in compression ignition engines.

The free fatty acid content of the pure biodiesels (MB₁₀₀, PKB₁₀₀) and that of the hybrid blends (MB₈₀PKB₂₀, MB₅₀PKB₅₀, MB₃₀PKB₇₀) were all found to be below 0.8 mgKOH/g which is the recommended limit according to ASTM D6571 standard (ASTM, 2002). However, pure moringa biodiesel (MB₁₀₀) and MB₈₀PKB₂₀ hybrid blend were slightly found to be the ASTM standard. The results of the free fatty acid contents is a reflection of the biodiesel yield from the trans esterification process carried. The lower the free fatty acid content the oil has the better the yield. However, MB₁₀₀ had the best yield, close to 100%. Hence, from research conducted by (Omonhinmin et al., 2020), a flash point of 6.678 was obtained, than those observed from table 2. Hence, significant quantity was obtained from the hybridization of pure feedstock, as a result of low free fatty acid content. From the foregoing analysis it could be inferred that all the hybrid biodiesel could be used in compression ignition engines.

The acid values obtained for the pure moringa and palm kernel biodiesels as well as hybrid biodiesels blends were found to be lower than that of the crude MOO and PKO. However, the acid value for MB₁₀₀ was discovered to be higher than that of PKB₁₀₀ and the hybrid biodiesel blend. The acid number of the hybrid biodiesel blends were found to be above the ASTM D6751 and EN 14214 standard of <0.8 and 0.5 mgKOH/g, respectively. Although, the acid number for the hybrid biodiesel fuels are better than that of the parent stocks (MB₁₀₀, PKB₁₀₀) and the crude MOO and PKO. Usually, the operating parameters, sometimes, tend to be at par with those of conventional biodiesel. The presence of

high content of peroxide (table 1), might not be unconnected with the high acid number observed. Also, the high acid number could have some negative effect on the fuel line components, corrosion and the results contribute to the formation of deposits, which has the tendency to clog the fuel filter and at the same time cause a reduction in fuel pressure. Therefore, the oil needs to be treated to have stability to oxidation so that it can be stored for a long period to avoid rancidity.

Flash point is simply described as the temperature at which biodiesel burns when in contact with ignition source. Hence, the value of the pure moringa and palm kernel biodiesels (MB₁₀₀, PKB₁₀₀) and those of the hybrid blends falls within the ASTM D6751 recommended limit of >130°C (ASTM, 2002 and EN 14214). The results as shown in table 2, reveals that the hybrid biodiesel fuels could be comfortably be used as fuel in compression ignition engines. In addition flash point of all hybrid biodiesel and pure biodiesel fuels tend to be within the acceptable standard than that of conventional diesel, which has a range of 60 -80°C (Omonhinmin et al., 2020). The high flash point the fuel indicates that the fuels have higher fire safety during transportation, handling and storage.

The saponification value of the pure biodiesel fuels MB₁₀₀ and PKB₁₀₀ were found to be 210.936 and 300.696 mgKOH/g as against 197.472 and 301.818 mgKOH/g, for crude MOO and PKO respectively as presented in table 1 and 2. From the results, it could be inferred that the saponification value for pure moringa biodiesel (MB₁₀₀) significantly improve while that of pure palm kernel biodiesel was almost stagnant. The hybrid biodiesel fuels possessed saponification in conformity with the acceptable maximum range of 195 – 261 mgKOH/g [ASTM 2002], with the exception of MB₃₀PKB₇₀ blend, which was found to be slightly higher than the maximum acceptable value. This variation in saponification value for the hybrid blend of MB₃₀PKB₇₀, could be associated with the high percentage of pure (PKB₁₀₀). In the same vein, increase in saponification value could be attributed to oxidation and polymerization reaction. Therefore, hybrid blends of MB₈₀PKB₂₀,

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MB₅₀PKB₅₀ could be used as fuel in a compression ignition engine.

The cloud point of the hybrid biodiesel blends has lower values than that of the parent stocks (MB₁₀₀, PKB₁₀₀). According to ASTM D6571 standard (ASTM, 2002), the cloud point is a function of location and season. Therefore, according to the results obtained for the hybrid biodiesel fuel blends ranges from 5.3 to 4.1°C. However, the results indicate that the hybrid biodiesel fuels could only be used in temperate regions, such as Nigeria. From the literatures, it was found that a cloud value at -7°C was obtained for a hybrid biodiesel fuel of moringa oleifera and jatropa biodiesels, for a blend ratio of 50/50 as reported by Eloia-Eboka and Inmbao (2016). Whereas, for ASTM D975 standard recommended limit of cloud value ranges between -3 to 12°C (Zubairu et al., 2021)

However, the pour point presented in table 2, represents the hybrid biodiesel fuels ability to flow before it can be gelled. Therefore, this parameter indicated the temperature at which the hybrid biodiesel may cease to flow. Hence, according to ASTM D6751 standard [ASTM, 2002], the recommended limit ranges from -15 to 10°C. From the results it could be inferred that the pure biodiesels and hybrid biodiesel blends have good pour points and can withstand critical conditions within the ASTM standard.

The calorific value of the pure moringa and palm kernel biodiesels (MB₁₀₀, PKB₁₀₀) were in agreement with those in found in literature (Mofijur et al., 2015 and Omonhinmin et al., 2020). However, the calorific values of the hybrid biodiesel fuels obtained were 41.016, 39.998 and 41.358 MJ/kg for MB₈₀PKB₂₀, MB₅₀PKB₅₀, MB₃₀PKB₇₀, respectively. The calorific values of pure biodiesel and that of hybrid biodiesel fuels are generally lower than that of conventional diesel because of the presence of oxygen which occupies space and contains small heating value (Mofijur et al., 2015). From the results presented in table 2, the calorific values of the pure and hybrid biodiesel fuels falls within the ASTM D6751 and EN 14214 standards recommended limits of 42 – 45 MJ/kg (ASTM, 2002), while the standard

calorific value of conventional diesel is given as 44.8 MJ/kg (Omonhinmin et al., 2020)

The sulphur content reported for pure moringa and palm kernel biodiesel and the hybrid biodiesel fuels all fall within the threshold value of 0.05%, according to standards (ASTM, 2002).

CONCLUSION

Moringa Oleifera and Palm Kernel seeds were processed to obtained crude moringa oleifera oil and palm kernel oil, using soxhlet extractor. The oil yields obtained from seeds were 27.42% and 44.70% for moringa oleifera and palm kernel, respectively. The oils were characterized according to FAO/WHO standard (CODEX, 2009). All the physicochemical properties conform to the stipulated standard except for peroxide parameter which exhibits higher values 12.0 and 14.0 mgKOH/g for moringa and palm kernel oils respectively, as against the recommended limit of 10 mgKOH/g. The high peroxide value may have to be treated with antioxidant to avoid deterioration of oils.

In situ hybridization process was employed to synthesize the hybrid biodiesel fuels according to the ratios MB₈₀PKB₂₀, MB₅₀PKB₅₀, MB₃₀PKB₇₀. The biodiesel yields from the transesterification process ranged between 93.3% and 97.6%. The hybridized biodiesel fuels were characterized according to ASTM D6751 and EN 14214 standards. The acid value of the hybridized biodiesel fuels was above the stipulated standard of 0.5 mgKOH/g. Therefore, the hybridized biodiesel fuels may need to be subjected to treatment process to avoid oxidation which may lead to rancidity. Also, the saponification value pure PKB₁₀₀ and hybrid blend MB₃₀PKB₇₀ are 300.696 and 286.110 mgKOH/g respectively, as against the recommended range of 195 – 261 mgKOH/g. The saponification may lead to oxidation and polymerization reaction, if not adjudged. All other properties were within the standard and therefore the hybridized fuel could be used in an internal compression ignition engine.

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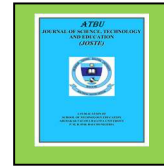
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