Extraction, Production and Characterizations of Diesel Produced From Palm Kernel Seeds

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Abstract: Due to growth of economy at 8% to 12% GDP for developing nations like India, China, Brazil and South Africa, the demand for energy and fossil fuel is ever increasing. This led to the need of exploring alternative fuels to meet the ever growing energy demands. Interestingly, vegetable oils as an alternate diesel engine fuels dates back several decades. There is need for ideal, renewable, cleaner and environmental friendly energy source in order to reduce the havoc caused by continuous dependence on conventional energy source. The present study aimed at producing biodiesel from alm kernel seeds. The soybean seeds were sun-dried for five days and grounded into fine particles with grinding machine. The oil was extracted from grounded soybean seeds by solvent extraction methods. The extracted oil was transesterified to biodiesel using sulphuric acid as a catalyst. The biodiesel was analyzed by Gas Chromatography Mass Spectroscopic (GC-MS). Physicochemical properties of biodiesel were determined using predictive models based on fatty acid composition and American Society for Testing for Materials (ASTM) protocols. Data obtained were subjected to appropriate statistical analysis. The fatty acid content of biodiesel had 52.20% saturated, 40.70% monounsaturated and 7.1% polyunsaturated fatty acids. The physicochemical properties of the methyl ester produced were : Colour (Colorless), specific gravity (0.8700), kinematic viscosity(2.41 mm^2/s at 40°C), flash point (134°C), cloud point (-9°C), pour point (-6°C), refractive index (1.46), heat of combustion (37MJ/kg), density (0.8700 g/cm^3), ash content (0.02%) , acid value (0.35mgKOH/g), saponification value (222 mgKOH/g), peroxide value (2.8 meq/kg), iodine value (44. 80mgI$_2$/g), free fatty acid (1.15 %), cetane number (71), oxidative stability (6.91 hrs), long chain saturated factor (25.10 ^{o}C), cold-filter plugging point (67.31^{o}C), degree of unsaturation (66.80), high heating value (44.80^{o}C) and water content (0.06). Palm kernel seeds biodiesel meet acceptable global requirements for biodiesel production. Hence, Palm kernel seeds are an ideal substitute and fits in as starting materials for production of diesel fuel.

Keywords: Bio-diesel, Palm kernel seeds, Renewable, Extraction Trans-esterification process.

1. INTRODUCTION

Current increase in energy use across the globe has been attributed to population growth which has brought about rise in industrial set up and economic development. All countries of the world rely on energy as a pivotal for sustenance of their growth and development. Energy serve as catalyst for effective running, proper functioning, high productivities and rewarding output of their operation which eventually contribute immensely to overall growth of the country.

Despite immense contribution to world development, energy also caused great havocs to human race, aquatic animals and also has great negative impact in environmental pollution. The aforementioned problems are linked to continue reliance on non-renewable energy sources. Non renewable energy are energy from natural origin that cannot be readily replaced through natural means at a quick enough pace to keep up with consumption.

Fossil energy is hazardous to our immediate environment through discharge of poisonous gasses that are detrimental to human and animal health. The use of fossil fuel is common all over the country in the world and they are not renewable, expensive, non sustainable while availability is for known limited period of time. Fossil energy are energy produced from fossil fuels while fossil fuels are fuel formed by natural processes.

Fossil fuels are mainly formed from fossilized, dead decayed, buried remains of plants and animals that exists millions years ago. The fossil fuels include Coal, natural gas and crude oil. Burning of these fossil fuels birthed the greenhouse gas carbon dioxide. One of the major causes of global warming is formation of carbon dioxide and other green house gases through burning of fossil fuels.

In Nigeria, one of the leadings fossil fuel is fossil diesel. Fossil diesel are fractional part of petroleum products commonly use in houses, various industrial set up to power generating set while some vehicles are also using it as fuel for their engines. Fossil

diesels are non- renewable, environmentally unfriendly and their source will be depleted at a specific time. Liquid fossil are the most commonly and frequently used fuels for mobile machinery and heavy industrial machines. The machinery of term of reference is not limited to basic well known means of transportation, but also to a wide range of machinery used in the construction business, industry, agriculture.

Going by the fact that the entire development of mobile machinery is based on the use of liquid fossil fuel, it is completely unrealistic with expectation of paradigm shift from this well known trend to a mass development and use of new engine constructions that would be suitable and appropriate for some other type of fuel. Rather, the scientists all over the world worked on discovering the fuel that would be adaptable to the existing engine constructions and would meet the criteria regarding renewability, ecology and reliability of use. Fulfilling aforementioned criteria is the basis for a successful and total fossil fuel replacement by some other types of fuel. Presently, renewable energy sources through biodiesel production has become the most common reliable renewable liquid fuel due to its ability to meet the set precursors of the previously highlighted criteria.

Palm kernel is presently among the world's largest oilseeds producers across the globe with estimated production of 18.59 million tons in 2017 (USDA, 2018). The world producers of palm oil are Indonesia, Malaysia, Thailand, Nigeria and Colombia while countries with the largest and highest production rate are Colombia and Thailand respectively (Index Mundi, 2018).

There are several methods for extraction of oil from palm kernel seeds; this includes mechanical extraction, solvent extraction, micro-emulsion, and extraction with supercritical fluids (Norhaizan et al., 2013). Employment and income generation, and consequently improvement in the quality of producer's life, trade development are social and environmental benefits of oil production (Aziz et al., 2015).

In respect of progress on culture and new areas of palm kernel applications, several alternatives have been studied as part of bid for improvement in crop and new technology along with methods to obtain the oil for development of new products such as biofuels, biodiesel, cosmetics, and food products (Bashir et al., 2015; Da Silva and Engelmann, 2017).

The use of palm kernel in biofuels production has been reported as an alternative starting material for diesel production from palm agro-industry (Sukiran *et al*., 2017). As a result of similar properties to diesel, biodiesel is an alternative to fossil fuels among biofuels. Biodiesel is a renewable source of energy, and when compared to diesel it is biodegradable, it presents lower toxicity, lower content of sulfurous, lower aromatic compounds, and lower emissions of particulates such as hydrocarbons, monoxide, and carbon dioxide (Farobie *et al*., 2016).

Biodiesel is a non-polluting fuel obtained from organic oils of vegetable origin chemically known as free fatty acid methyl ester (FAME). The esters of fatty acids derived from transesterification of vegetable oils have properties closer to diesel fuels. These fuels tend to burn cleaner; perform comparably to conventional diesel fuel (Sharma and Bhaskar Singh, 2010). Irrespective of the difficulties mentioned above, esters of vegetable oils prove to be one of the alternate options to substitute the diesel fuel in future. Biodiesel is a clean, renewable, non-toxic, bio-degradable, free from Sulphur with higher Cetane value and enhanced oxidizing property leading to better combustion which can be used in any CI engine without major modification (Xu and Wu, 2003).India with a large non-arable and primarily agricultural based nation, cultivating crops for producing vegetable oils for energy sector will not be a great burden.

In this study, biodiesel is produced from kernels of Palm through two stage transesterification process. The characterization of Palm kernel biodiesel is carried out to analyze it utility as a biodiesel to be used in compression ignition engine using Gas Chromatography Mass Spectrometry.

2.0 METHODOLOGY

2.1 Sample collection and preparation

The palm kernel seeds were obtained from Ilesha, Osun state, Nigeria. They were taken to Biology Laboratory at Department of Science and Laboratory Technology, Osun State College of Technology, Esa Oke. The palm kernel seeds were sundried for five days and grounded into powdery form by grounding machine.

2.2 Extraction of oil from grounded powdery Palm kernel seeds

The oil was extracted by the Bligh and Dyer method (Bligh and Dyer, 1959) modified by Nascimento*et al*., 2013. A mixture of 2 ml methanol and 1 ml chloroform (2:1) was made and added to 1 g grounded palm kernel seed. The mixture was kept for 24 h at room temperature to dissolve the lipids properly. It was centrifuged at 3000 rpm for 10 min and supernatant was collected. The process was repeated by adding 2 mL of chloroform to the pellet and shaken properly. It was again centrifuged at 3000 rpm for 5min and supernatant was separated. After adding 2 mL of 1% potassium chloride (KCL) to the supernatant, two separate layers were formed. The upper layer (methanol/powdered palm kernel seed) was decanted and the lower chloroform layer containing the

extracted lipids was collected in another test tube. The upper layer (methanol/powdered palm kernel seeds) was extracted again using the same procedure but with 1 mL of 1% potassium chloride (KCL). The bottom phase (chloroform/lipids) were combined and evaporated for 24 h in a drying oven at 80°C.

2.3 Trans-esterification of Palm kernel oil (PKO) to Fatty Methyl Ester (FAME)

This was achieved using the Lepage and Roy (1994) method, with slight modifications by Anitha and Sriman (2012). The crude palm Kernel oils (about 10 mg) was dissolved using 2 mL of a freshly prepared mixture of chloroform-methanol (2:1, v/v) in a 10 mL Pyrex tube with a Teflon-sealed screw cap. 1 mL of methanol as reagent and 0.3 mL of sulfuric acid 95-97 % (ScharlauChemie, reagent grade) as catalyst was added, for the trans-esterification of about 10 mg of oils. After screwing the lid, the tube with the mixture was weighed and vigorously shaken for 5 min. Finally, the tube was incubated at 100 °C for 10 min and cooled to room temperature. Followed by addition of 1 mL of distilled water for phase separation (by adding water two distinct phases are formed, the upper layer rich in water, methanol, glycerol, and sulphuric acid, and the lower layer rich in chloroform and esters). Then, 1 mL of distilled water was added for a gentle water washing of esters with chloroform layer (more dense than the water layer) followed by discard of the water rich upper layer (less dense). This step was repeated twice more. The esters rich layer was filtered using a disposable Nylon syringe filter (0.2 μm pore, 13 mm diameter, Cronus, UK). The chloroform was then evaporated to dryness from the esters in a laboratorial hood, at room temperature (of about 25ºC).

2.4 Gas Chromatography and Mass spectroscopic of Palm kernel Fatty Acid Methyl Ester

The FAME obtained from the palm kernel oil was analyzed according to the method described by Medina *et al*. (1998) using a Shimadzu 2010 gas chromatography (Shimadzu Scientific Instruments, Columbia, MD, USA) equipped with a flame Ionization detector and a diethylene glycol succinate capillary column (30m × 0.25 ×0.25 μm). Both initial column temperature and injection port temperature were 180°C. Detector temperature is 230°C, and was increased to 300°C at a temperature gradient of 15°C/min. Biodiesel sample (100 μL) was placed into capped test-tubes, saponified with 1 ml of saturated KOH-CH₃OH solution at 75°C for 10min, and then it was subjected to methanolysis (Schreiner, 2006) with 5% HCL in methanol at 75°C for another 10 min. Thereafter, the Phase containing the fatty acid methyl esters was separated by adding 2 mL of distilled water, and methanol was recovered. The components were identified by comparing their retention times and fragmentation patterns with those of the standards. Six fatty acid methyl esters (C16:1, C17:0, C18:1, C18:2 and C18:3) were used as the standard materials.

2.5 Physicochemical Characterization of the Palm Kernel Seed Methyl Esters Produced

2.5.1 Specific Gravity

A 3ml aliquot of the methyl ester was weighed and its density calculated using the equation below

$$\text{Density (\%)} = \frac{\text{Mass of Methyl ester(g)}}{\text{Volume of water(ml))}} \times 100$$

Then, the specific gravity of the methyl ester was calculated using the formula in equation below

$$\text{Specific gravity (\%)} = \frac{\text{Density of Methyl Ester (g)}}{\text{Density of water(g)}} \times 100$$

2.5.2 Relative density

This was carried out using the method described by ASTM D6751 (2009). The mass was obtained by weighing the empty and filled (Palm Kernel Seed methyl ester) Erlenmeyer flask. The difference was the mass of the Palm oil methyl ester. With these two values, the density was obtained, which is mass divided by volume.

2.5.3 Moisture content

This was determined by method described by AOCS. Cd 3-25 (1998) An empty flask was weighed with and without the amount of methyl ester and dried in an oven at 105°C for 7h, weighing each 2 hours till a constant weight was obtained, and finally the weight was taken and compared with the initial recorded weight. The percentage moisture content was calculated using below following equation.

$$\text{Moisture content (\%)} = \frac{(W1 - W2)\ (g)}{W2(g)} \times 100$$

Where,

W_1 = Original weight of the sample before drying

W_2 = Weight of the sample after drying

2.5.4 Viscosity

This was done using the method of AOAC (1998). Methyl ester was gradually poured into the viscometer until its lobe was almost filled and then it was placed in a water bath and allowed to heat up to an equilibrium temperature of 40°C. The methyl ester on the broad arm was sucked through the narrow arm until it reached the upper mark above the lower lobe of this narrow arm. The methyl ester was then allowed to flow back to the lower mark just below the lower lobe. The time taken for the flow (flow time, t) was recorded. Then, the viscosity was calculated using below equation:

Viscosity (%) $= \frac{Vp_1t_1}{p_2t_2} \times 100$

Where,

n = Viscosity of the methyl ester mm^2/s

v = Viscosity of water mm^2/s

p_1 = Density of the methyl ester, Kg/m^3

p_2 = Density of water, Kg/m^3

t_1= Time taken for the Palm kernel seeds methyl ester to flow back

t_2 = Time taken for the water to flow back

2.5.5 Flash Point

The flash point was determined according to open cup method described by ASTM D6751, (2009). The cup was filled with a sample of the methyl ester up to the mark (75ml) and the cup was heated with a Bunsen burner maintaining a small open flame from an external supply of natural gas. Periodically, the flame was passed over the surface of the methyl ester. When the flash temperature was reached, the surface of the methyl ester caught fire. The temperature (at the moment) was noted and recorded as the flash point temperature.

2.5.6 Cloud Point

This was carried out based on the ASTM D6751, (2009) method. A test tube with a thermometer inserted in it, was filled with a sample of the methyl ester. The methyl ester was cooled at 2°C/min rate and continuously monitored until a white cloud appeared on the bulb of thermometer. The temperature that corresponds to the first formation of a cloud in the methyl ester was recorded.

2.5.7 Pour Point

This was carried out using method described by ASTM D 97-96a (1998). A sample of the methyl ester in a capillary tube was solidified; thereafter, it was attached to a thermometer and inserted into a gradually heating beaker of water. The temperature at which the sample started moving in the capillary tube was recorded as pour point.

2.5.8 Percentage ash content

The ASTM D874,(2007) method was used for the determination of percentage ash content. To a washed porcelain crucible, One gram of palm oil methyl ester was added. It was weighed after drying and cooling in an oven at 100°C and a desiccator respectively. Then, heated for 4 hours at 600°C inside a muffle furnace, after which it was removed and subsequently cooled in a dessicator and weighed again. The percentage ash content was calculated using below equation:

Ash content (%) $= \frac{A-B}{C} \times 100$

Where,

A = Weight of crucible + ash,

B = Weight of crucible

C = Weight of original sample

2.5.9 Refractive Index

This was determined according to the method of Alamu *et al*. (2008) using a refractometer (Abbe refractometer bench). The power switch was turned on; the illuminating lamp came up and the display showed 0000. A drop of the methyl ester was introduced on the working surface of the lower refracting prism. The rotating arm and the collecting lens cone of the light gathering illuminating units were rotated so as to make the light-intake surface of the upper light-intake prism to be illuminated evenly. The field of view was observed through the eye piece and the adjustable hand wheel was rotated so as to make the line dividing the dark and light areas fall in the cross line. The dispersion correction hand wheel was rotated so as to get a good contrast between the light and dark area and minimum dispersion. The read button was pressed and the refractive index was displayed on the screen

2.5.10 Conductivity

This was determined using a conductivity meter. The conductivity meter was standardized with 0.01M KCl solution. The electrode was rinsed with deionized water, wiped and dipped into a sample of the ethyl ester and left for some time to stabilize the reading. The reading was displayed on the screen and then recorded in micro Siemens per centimeter (μS/cm).

2.5.11 Heat of Combustion

This was carried out using a bomb calorimeter by method of AOAC (1998). The calorimeter was standardized using benzoic acid. To a crucible of the calorimeter, a weighed amount of the methyl ester (1.058g) was added and the fuse wire was attached between the electrodes. Thereafter, it was placed in the bomb, which was pressurized to 18atm of oxygen. The bomb was placed in a vessel containing a measured quantity of water (2000g). The ignition circuit was connected and the water temperature was noted. After ignition, the temperature rise was monitored every minute till a constant temperature was reached and recorded. The pressure was released, the length of unburned fuse wire was measured and the residue titrated with 0.7M of sodium carbonate solution using phenolphthalein as indicator. The heat of combustion was calculated using below equation:

$$\text{Heat of Combustion} = \frac{E\Delta T - 2.3V}{g(KJ/Kg)} \times 100$$

Where,

E = Energy equivalent of the calorimeter using benzoic acid

ΔT = Temperature rise

L = Length of burnt wire

V = Titration volume

g = Weight of sample

2.5.12 Acid Value

This was determined by method of ASTM D6751 (2009). A standard alcoholic KOH solution (0.5M) was prepared by dissolving KOH (pellet) with ethanol. The solution was then filtered and stored in brown bottle for Five days. Furthermore, a mixture of 95% ethanol and diethyl ether in a ratio of 1:1 (v/v) was prepared. 5 grams of the methyl ester was dissolved in 25ml of 1:1 (v/v) mixture of ethanol and diethyl ether. The solution was titrated with 0.5M ethanolic KOH solution in the presence of 5 drops of phenolphthalein as indicator until the end point (colorless to pink) was recognized. The total acidity (acid number) in KOH/g was calculated using below equation.

$$\text{Acid value} = \frac{V \times N \times 56.1}{M}$$

Where,

V= Volume expressed in milliter of 0.5M solution of ethanolic KOH,

M= Weight of the sample in gram

N= Concentration of ethanolic KOH

2.5.13 Peroxide Value

The method of AOAC (1998) was used for the determination of peroxide value. To a 30 ml of mixture of glacial acetic acid and chloroform (3:2, v/v), 2.206g of the methyl ester was dissolved in the mixture, then, 20% of potassium iodide (0.5 ml) was added and the solution swirled in the dark for one minute after which 75ml of distilled water was added. The mixture was titrated with 0.1M sodium thiosulphate with vigorous shaking until the yellow colour of the iodine had disappeared. Starch indicator (0.5ml) was added then to obtain a blue colour and titration continued until all the blue colour had disappeared. The peroxide value was calculated using below equation:

$$\text{Peroxide Value} = \frac{(S-B) \times M \times 100}{\text{Sample weight(g)}}$$

Where,

S = Sample titre value in ml

B = Blank titre in m

M = Molarity of Sodium thiosulphate

2.5.14 Iodine Value

This was determined using the method of AOAC (1998). An aliquot of the methyl ester (0.8825g) was weighed into a conical flask, tetrachloromethane (15ml) and 25 ml of Wig's solution was added. This mixture was placed in a stopper conical flask, swirled gently and placed in a dark cupboard for one hour after which 20 ml of 20% potassium iodide solution and 100ml of distilled water were added. After gentle shaking, liberated iodine was titrated with 0.1M sodium thiosulphate solution until the yellow colour of the iodine had appeared. Starch indicator (1ml) was added then to obtain a blue colour and titration continued until all the blue colour had disappeared. The iodine value was calculated using below equation

$$\text{Iodine Value} = \frac{(B-S) \times M \times 100}{\text{Sample weight(g)}}$$

Where,

S = Sample titre value in ml

B = Blank titre in ml

M = Molarity of Sodium thiosulphate

2.5.15 Percentage Free Fatty Acid

This was carried out using the method of AOAC (1998). Two grams of the methyl ester was weighed into a conical flask and 10 ml of 95% ethanol was added. This was then titrated with 0.1 M sodium hydroxide using phenolphthalein as an indicator. The conical flask was shaken constantly until a pink colour that persisted for 30 seconds was obtained. The percentage free fatty acid was obtained from the equation below

$$\text{Free Fatty Acid} = \frac{V \times M \times 2.92}{\text{Sample weight(g)}} \times 100$$

 Where,

V= Volume of 0.1M Sodium hydroxide used in ml

M= Molarity of NaOH.

2.6 Determination of other Properties Based on Fatty Acid Methyl Esther (FAME) Profiles

This was achieved using predictive models of Fatty Acid composition. Saponification value (SV), iodine value (IV), Cetane number (CN) degree of unsaturation (DU), long chain saturated factor (LCSF) and cold filter plugging point (CFPP) was determined by equations proposed by Islam *et al* . (2015):

$$SV = \sum (560 \times A_i) / M_{wi}$$

$$IV = \sum (254 \times A_i \times D) / M_{wi}$$

$$CN = 46.3 + (5458/SV) - (0.225 \times IV)$$

$$DU = \sum MUFA + (2 \times PUFA)$$

$$LCSF = 0.1 \times (C16:0, wt\%) + 0.5 \times (C18:0, wt \%) + 1 \times (C20:0, wt \%) + 1.5 \times (C22:0, wt\%) + 2.0 \times (C24:0, wt\%)$$

$$CFPP = (3.1417 \times LCSF) - 16.477$$

Where, D is the number of double bonds, M_W is the fatty acid (FA) molecular mass, and A_i is the percentage of each fatty acid (FA) component of the palm oil.

The kinematic viscosity (υ), density (*ρ)* and higher heating value (HHV) of each Fatty Acid Methyl Ester (FAME) were determined by equation proposed by Ramirez-Verduzco*et al*. (2012):

$$In (vi) = -12.503 + 2.496 + In (Mi) - 0.178 \times N$$

$$\rho = 0.8463 + 4.9/Mi + 0.0118 \times N$$

$$HHVi = 46.19 - 1794/Mi - 0.21 \times N$$

Where,

(*vi* is the kinematic viscosity of at 40 °C in mm2/s; *ρi*is the density at 20 °C in g/cm^3; *HHVi* is the higher heating value in MJ/kg of *i*th FAME, N is the number of double bonds, M_i is the molecular mass of each fatty acid component.

Predictive oxidative stability was calculated based on C18:2 and C18:3 content of Fatty Acid composition as suggested by Park *et al*.(2008):

$$OS = 117.9295/ (wt\% C_{18.2} + wt\% C_{18.3} + 2.5905 (0<100)$$

Where,

wt% $C_{18.2}$is the content of linoleic, wt% $C_{18.3}$ is the content linolenic acids (wt%) (0 <*X* < 100); and *OS* is the oxidation stability in hours.

4. RESULT AND DISCUSSION

Chromatogram of diesel obtained from Palm kernel oil was shown in Figure 1. The composition, quality and quantity of fatty acids in biodiesel of palm kernel seed were examined through Gas Chromatography and Mass spectroscopy analysis and Chromatogram is indicated in Figure 1 below. Thirteen fatty acids were obtained from characterized biodiesel extracted from palm kernel oil namely: Myristic Acid, Palmitic acid, Palmitoleic, Stearic acid, Oleic acid, Linoleic acid, Linolenic acid, Arachidic acid, Gondoic acid, Behenic acid, Erucic acid, Linoceric acid and Nervonic acid (Table 1). The biodiesel found in the palm kernel seeds had thirteen fatty acids with percentage composition, namely Myristic acid 7.8%, Palmitic acid 24.4%, Palmitoleic 10.35%, Stearic acid 16.60%, Oleic acid 27.15%, Linoleic acid 4.00%, Linolenic acid 3.1%, Arachidic acid 1.8%, Gondoic acid 1.2%, Behenic acid 1.2%, Erucic acid 1.7%, Linoceric acid 0.4 and Nervonic acid 0.3% (Table 1). The highest Carbon Carbon chain $C_{16} - C_{18}$ of 85.6% was recorded in diesel of Palm kernel seed while percentage composition of saturated, monounsaturated and polyunsaturated fatty acids in the biodiesel extracted from lipids were 52.2%, 40.70% and 7.1% respectively (Table 1).

The volatile matter of palm kernel diesel is 99.30 (Table 2), the value recorded conform satisfactorily to standards. Kinematic viscosity is a measure of a fluid's resistance to flow.

The greater the viscosity, the less easily the liquid will flow. The viscosity of fuels is a function of temperature and decreases as the temperature is increased. Biodiesel is usually more viscous than diesel fuel even though it is only by a small amount. The viscosity of biodiesel is very important since it affects the operation of fuel injection equipment particularly at low temperatures when the increase in viscosity affects the fluidity of the fuel or leakage at high temperature when too thin. (Bello and Agge, 2012).The kinematic viscosity of palm kernel biodiesel is 2.41 mm^3/s. The palm kernel biodiesel viscosity obtained showed 65% reduction from the kinematic viscosity of palm kernel oil thus enhancing biodiesel fluidity.

The values of refractive index obtained for palm kernel biodiesel is (1.46) and it conform satisfactorily with required biodiesel standard (US (ASTM D6751- 08) Table 2.

The values obtained for cloud point is -9 and conform within US (ASTM D6751- 08) standard range of -3 - +12 (Table 2).

The cold flow temperatures of biodiesel are very important quality criteria as fuel that is frozen can cause blockage of the fuel lines and filters and then starve the engine of fuel. The two most important criteria are the cloud and pour points. The cloud point is the temperature at which the amount of wax in the fuel is sufficient to gel it, thus making it the lowest temperature at which the fuel can flow (Bello and Agge, 2012).

The pour point is the temperature at which the fuel would not pour even when the containing vessel is tilted. The cold flow characteristics of biodiesel depends on chain length and degree of unsaturation, with long chain saturated fatty acid esters displaying particularly unfavorable cold temperature behavior. The cloud point of Pam kernel biodiesel is -9°C and pour point of Palm kernel biodiesel – 6°C. The pour point and cloud point of palm kernel oil reduces on transesterification.

The flash point is the lowest temperature to a barometric pressure of 101.3kPa at which liquid sample provides sufficient vapour for the air-vapour mixture above the surface to flash momentarily on exposure to standard source of ignition. It is a measure of flammability of fuels therefore making it an important safety criterion in transportion and storage. The flash point of biodiesel obtained is 134 and fall within the US (ASTM D6751- 08)130min and EN 14214 120min biodiesel standard (Table 2). The flash point of Palm kernel biodiesel decreases after transesterification, showing that the volatile characteristics have improved thereby making it more volatile.

The standard value for heat of combustion as stipulated by US (ASTM D6751- 08) and EN 14214 is min 35, the values recorded for palm kernel diesel 37.00 and it meet the set standard (Table 2).

 The density of palm kernel biodiesel is 0.8700 (Table 2) and it fall within the standard range (0.86 – 0.90g/cm^3). The ash content of palm kernel biodiesel (0.02) is within the standard value (US (ASTM D6751- 08) . The acid value (0.35 mgKOH/g) for palm kernel biodiesel is within the ASTM D6751- 08 and EN 14214 standard value of 0.5 for biodiesel (Table 2). The saponification value (MgKOH/g) of 222 was obtained for biodiesel extracted palm kernel seeds. The result recorded for free fatty acids (%) in biodiesel of palm kernel diesel is 1.15 (Table 2).

The iodine value is the amount of unsaturation in fatty acids. The unsaturation is in the form of double bonds which reacts with iodine compounds. The higher the iodine number, the more C=C bonds are present in the fat. The Iodine value in Palm kernel biodiesel is 44.80mgI^2/g respectively indicating the presence of small number of C=C bonds in the oil as a result of the high degree of saturation. The inflexure point for good fuel quality is 100 hence the biodiesel would be suitable for use as alternative fuel for diesel engines as far as carbon deposit formation is concerned. It would also have high oxidative resistance and semisolid at room temperature. When exposed to air, atmospheric oxygen would break the double bonds and convert them to peroxide. Cross-linking will take place at the sites and the oil is irreversibly polymerizes (drying) into plastic like substance.

Biodiesel can oxidize during storage and handling and in the presence of heat and air, leading to the formation of peroxides, acids, gums and deposits. The peroxide value palm kernel diesel is 2.8 (Table 2). These values are important from the point of view of fuel stability in storage. High level of saturation will have high oxidative and thermal stability due to the presence of fewer vacant chains, leading to a slower deterioration rate of the lipid characteristics (Lin and Chiu, 2010).

Cetane Number (CN) is a measure of the ignition quality of diesel and biodiesel fuels. The CN of palm kernel biodiesel is 71 and fall within the ASTM D6751- 08 and EN 14214 biodiesel standard (Table 2). For diesel engine usage, it is an important factor, as it affects cold startability, idlibility, engine noise, engine vibrations and incompleteness of combustion that can increase harmful exhaust emissions. (Ladammatos and Goacher, 1995)

Oxidative stability (hr) of 6.91 observed in biodiesel obtained from palm kernel diesel conforms satisfactorily within ASTM D6751- 08 and EN 14214 biodiesel standard (Table 2).The biodiesel obtained from oil extracted from palm kernel seeds had 25.10

long chain saturated factor (LCSF) and its fall within the ASTM D6751- 08 and EN 14214 biodiesel standard . The degree of unsaturation in palm kernel biodiesel is 66.80, the higher heating value 44.80 while water content is 0.06 (Table 2).

For Saturated fatty acids, the molecules harden at higher temperature and are solid at room temperature. As the biodiesel cools down, solid crystal are formed which can plug fuel filters hence the name cold flow plugging point. This temperature is called the cold flow plugging point. The plugging point for biodiesel was $67.31^{o}C$ which is higher than the ambient temperature (Table 2).
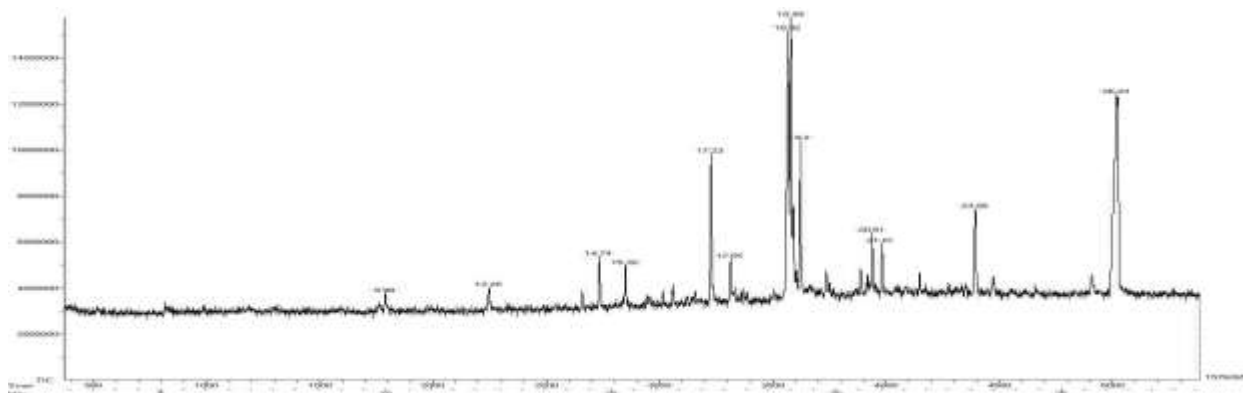

Figure 1: Chromatogram of diesel obtained from Palm kernel oil

Table 1: Gas Chromatography and Mass Spectroscopic of Palm kernel oil diesel showing Fatty Acids composition in percentage of Total Fatty Acid Methyl Esters components

Structure	Fatty Acids	Molecular Formula	Palm kernel seed biodiesel
			Percentage Composition of each Fatty Acids
$C_{8:0}$	Caprylic Acid	$C_8H_{16}O_2$	-
$C_{10:0}$	Capric Acid	$C_{10}H_{20}O_2$	-
$C_{12:0}$	Lauric Acid	$C_{12}H_{24}O_2$	
$C_{14:0}$	Myristic Acid	$C_{15}H_{30}O_2$	7.8
$C_{14:1}$	Tetradecanoic Acid	$C_{15}H_{28}O_2$	-
$C_{16:0}$	Palmitic Acid	$C_{16}H_{32}O_2$	24.40
$C_{16:1}$	Palmitoleic Acid	$C_{16}H_{30}O_2$	10.35
$C_{17:0}$	Margaric Acid	$C_{17}H_{34}O_2$	-
$C_{18:0}$	Stearic acid	$C_{18}H_{36}O_2$	16.60
$C_{18:1}$	Oleic Acid	$C_{18}H_{34}O_2$	27.15
$C_{18:2}$	Linoleic Acid	$C_{18}H_{32}O_2$	4.00
$C_{18:3}$	Linolenic Acid	$C_{18}H_{30}O_2$	3.1
$C_{19:0}$	Nonadecanoic Acid	$C_{19}H_{36}O_2$	-
$C_{19:1}$	II-Nonadeceonic Acid	$C_{19}H_{32}O_2$	-
$C_{20:0}$	Arachidic Acid	$C_{20}H_{40}O_2$	1.8
$C_{20:1}$	Gondoic Acid	$C_{20}H_{38}O_2$	1.2
$C_{20:4}$	Arachidonic Acid	$C_{20}H_{32}O_2$	-
$C_{20:5}$	Timnodonic Acid	$C_{20}H_{30}O_2$	-
$C_{22:0}$	Behenic Acid	$C_{22}H_{44}O_2$	1.2
$C_{22:1}$	Erucic Acid	$C_{22}H_{42}O_2$	1.7

$C_{22:5}$	Docsapentaenoic Acid	$C_{22}H_{34}O_2$	-
$C_{22:6}$	Docosahexaenoic Acid	$C_{22}H_{32}O_2$	-
$C_{24:0}$	Linoceric Acid	$C_{24}H_{48}O_2$	0.4
$C_{24:1}$	Nervonic Acid	$C_{24}H_{46}O_2$	0.3

$C_{16-C_{18}}$ (%)	85.6
Saturated Fatty Acid (%)	52.20
Monounsaturated Fatty Acid (%)	40.70
Polyunsaturated Fatty Acid (%)	7.1

Table 2: Physico-chemical properties of Diesel extracted from the Palm kernel oil in comparism with US (ASTM) D6751-08 and Europe (EN 14214) standard

S/N	Physicochemical parameters	Palm Kernel diesel	USA (ASTM) D6751-08	EUROPE (EN 14214)
1	Specific Gravity	0.8700	0.88	
2	Kinematic Viscosity (mm^2/s) at 40^{0}c	2.41	1.9-6.0	3.5-5.0
3	Flash Point (^{0}C)	134	130min	120min
4	Cloud Point (^{0}C)	-9	-3-+12	-
5	Pour Point (^{0}C)	-6	- 15 - +10	-
6	Volatile Matter (%)	99.30		
7	Refractive Index	1.46	1.479	
8	Heat of Combustion (MS/kg)	37.00	35min	35min
9	Conductivity (MS/cm)			
10	Density (g/cm^3)	0.8700	0.86-0.90	
11	Ash Content (%)	0.02	0.01	0.02
12	Acid Value (mgKOH/g)	0.35	0.5	0.5
13	Saponification Value (mgKOH/g)	222		
14	Peroxide Value (meq/kg)	2.8		
15	Iodine Value (mgI$_2$/g)	44.80		120max
16	Free Fatty Acid (%)	1.15		
17	Cetane Number	71	47min	51min
18	Oxidative Stability (hr)	6.91		3.0min

19	Long Chain Saturated Factor (LCSF)^{0}C	25.10		
20	Cold-Filter Plugging Point (CFPP)	67.31		
21	Moisture Content (%)			
22	Degree of Unsaturation	66.80		
23	High Heating Value (HHV)	44.80		
24	Water Content	0.06	500ppm	500max
25	Calorific Value (Kcal/kg)			

5. CONCLUSION

During the investigation, it was confirmed that Palm kernel seeds may be used a resource to obtain biodiesel. Palm kernel oil can be extracted from Palm kernel seeds and converted into methyl esters and the properties are within the limits for biodiesel. The experimental result shows that alkaline catalyzed transesterification is a promising area of research for the production of biodiesel on a large scale. Biodiesel characteristics are comparable to that of diesel thereby making it feasible as a means of alternative fuel for diesel engines

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