ISSN 2056-5860

CHARACTERIZATION AND ENGINE TESTING OF PALM KERNEL OIL BIODIESEL

E. I. Bello, B. Oguntuase, A. Osasona, T. I. Mohammed
Department of Mechanical Engineering
The Federal University of Technology, Akure, **NIGERIA**

ABSTRACT

Industrial grade Palm kernel oil was purchased from a local dealer, filtered and dried before transesterification using methanol as reagent and sodium hydroxide as catalyst. The biodiesel was characterized and found to have similar properties to diesel fuel. The fatty acid profile was determined using chromatographic analyzer to which is connected Flame Ionization Detector and used hydrogen as the carrier gas. The printout showed that the oil contains mainly 46% lauric acid and 23 % palmitic acids giving a 78% total saturated. The biodiesel and 20% blend with diesel and diesel were tested in a single cylinder engine coupled to a dynamometer. The torque and power developed by biodiesel are lower than those of diesel while those of the blends lied between diesel and biodiesel.

Keywords: Palm kernel oil, biodiesel, characterization, torque, power.

INTRODUCTION

The high energy demand for fossil diesel in the industrialized world and the pollution problems resulting from widespread use of fossil fuels makes it increasingly necessary to develop renewable energy sources of limitless duration and limited environmental impact. Many researchers have concluded that vegetable oil hold promise as alternative fuels for diesel engines. However, the use of raw vegetable oils for diesel engine is problematic due to high viscosity and low volatility that can lead to severe engine deposit, injector coking and piston ring sticking (Leung et al., 2010, De Oliveira et al., 2009). The problems and effects can be eliminated through transesterification of the vegetable oils to biodiesel. The whole world is facing the crises of depletion of fossil fuels as well as the problem of environmental degradation. The rapid depletion of fossil fuel reserves with increasing demand and uncertainty in their supply, as well as the rapid rise in petroleum prices, has stimulated the search for other alternatives to fossil fuels. Many alternative fuels are being evaluated as potential alternatives for the present high-polluting diesel fuel derived from diminishing commercial resources. Biodiesel has emerged as one of the most energy-efficient environmentally friendly alternatives in recent times to meet the future energy needs. Biodiesel is a renewable diesel substitute that can be obtained by chemically reacting any vegetable oil or fat with an alcohol. During the last 15 years, biodiesel has progressed from the research stage to a large scale production in the United State and many other countries. Many vegetable oils, animal fats and recycled cooking greases can also be transformed into biodiesel and can be used neat or as a diesel additive in compression ignition engines.

Historical Background of Biodiesel

Rudolf Diesel, who invented the first Diesel Engine in 1895 (German patent 672), used peanut (groundnut) oil to run his engine. His visionary statement was "*The use of vegetable*

ISSN 2056-5860

oils for engine fuel may seem insignificant today, but such oils may become in course of time, as important as petroleum and coal tar products of the present time". The above prediction is becoming true today as more and more biodiesel is being used all over the world. In 1900 at the world fair in Paris, organized by the French Society for the support of the Otto engine, a small version of his diesel engine fuelled with peanut oil was demonstrated. It was a major innovation as at that time because cheap crude oil was available in abundance, which made vegetable oils unattractive as a source of fuel much.

Properties of Vegetable Oils and Biodiesel

Diesel fuel molecules are saturated non-branched hydrocarbon molecules with carbon chain length ranging from 12 to 18 whereas vegetable oil molecules are triglycerides generally with un-branched chains of different lengths and different degrees of saturation. Vegetable oils mainly contain triglycerides (90 to 98%) and small amounts of mono- and di-glycerides. Triglycerides are esters of three fatty acids attached to a glycerol molecule. Vegetable oils and biodiesel are biodegradable, non-toxic, and clean fuels. Vegetable oils and their derivatives as diesel engine fuels and lead to substantial reductions in sulfur, carbon monoxide, polycyclic aromatic hydrocarbons, smoke and particulate emissions. A number of vegetable oils like karanja oil, rapeseed oil, rice bran oil, cottonseed oil, sunflower oil and jatropha oil have been investigated as fuel in diesel engines (Vyas et al., 2009; Antony et al., 20121; Gui et al., 2008; Dorado, 2007) Studies indicate that, over short periods of time, neat vegetable oil perform satisfactorily in unmodified diesel engines. Vegetable oils have high viscosity due to large molecular weight and bulky molecular structure (Anastopoulos et al., 2009), The viscosity of liquid fuels affects the cold flow properties as well as spray atomization, vaporization, and air/fuel mixture formation. Higher viscosity also has an adverse effect on the combustion of vegetable oils in existing diesel engines, fuel pumps and injectors. Temperature greatly affects the viscosity of vegetable oils. It has been reported that the viscosity of oils and fats decreases almost linearly with temperature. The flash point of vegetable oils is usually very high (above 180^0 C) and the heating values are in the range of 36 – 40 MJ/kg, as compared to diesel fuels which is about 42-45 MJ/kg. The presence of chemically bounded oxygen in vegetable oils lowers their heating values by about 10%. The cetane numbers are in the range of 30–45. Vegetable oils have comparable energy density, cetane number, heat of vaporization, and stoichiometric air/fuel ratio to that of mineral diesel. Vegetable oils can be mixed with conventional diesel in any proportion and blends have been used successfully in diesel engines. Biodiesel fueled engine emits lower polluting species without the need for additional emission control equipment. The characteristics of biodiesel are close to diesel fuels and therefore biodiesel becomes a strong alternative to replace the diesel fuel. The conversion of triglycerides into methyl or ethyl esters through the transesterification process reduces the molecular weight to about one-third that of the triglyceride and reduces the viscosity by a factor of about eight and increases the volatility marginally. These esters contain 10 to 11% oxygen by weight, which may encourage more combustion than hydrocarbon based diesel fuels in an engine. Biodiesel has lower volumetric heating values (about 12%) than diesel fuels but has a high cetane number and flash point (Canakci and Gerpen, (1998)).

Fuel Formulating Techniques

The alternative diesel fuels must be technically and environmentally acceptable and economically viable. From the viewpoint of these requirements, triglycerides (vegetable oils/animal fats) and their derivatives shall be considered as viable alternatives to diesel fuels.

ISSN 2056-5860

The problems with substituting triglycerides for diesel fuels are mostly associated with their high viscosities, low volatilities and polyunsaturated character. One of the main problems of vegetable oil use in diesel engines is their higher kinematic viscosity because of heavier triglycerides and phospholipids, due to which problems occur in pumping and atomization, ring-sticking, carbon deposits on the piston, cylinder head, ring grooves, etc. Straight vegetable oils are less suitable as fuels for diesel engines; since they have to be modified to bring their combustion related properties specially viscosity closer to mineral diesel. Heating or pyrolysis, dilution or blending, micro-emulsification and transesterification are some well known techniques available to overcome higher viscosity related issues associated with the use of vegetable oil in diesel engines and to make them compatible to the hydrocarbon-based diesel fuels.

Transesterification Process

Transesterification is a most suitable process to convert oils and fats into biodiesel. It is the most popular reaction used for the conversion of vegetable oils into biodiesel in order to reduce its viscosity. It is the reaction of an alcohol, in most cases methanol, with the triglycerides present in oils, fats or recycled grease, forming biodiesel (fatty acid alkyl esters) and glycerol. The reaction requires heat and a strong base catalyst, such as sodium hydroxide or potassium hydroxide. The transesterification process involves reacting vegetable oils with alcohols such as methanol or ethanol in the presence of a catalyst (usually sodium hydroxide or potassium hydroxide) at about 60^0 C to give the ester and the byproductperformance than neat vegetable oils. (Satyanarayan and Muraleedharan, 2010). Formo 1954), in his research confirmed that alcohols such as ethanol, glycerin. It has been reported that the methyl and ethyl esters of vegetable oil can result in superior, methanol or butanol can be used in transesterification and these alcohols esters are named methyl esters, ethyl esters or butyl esters respectively. The most commonly preferred catalyst are sulphuric, sulphonic and hydrochloric acids as acid catalysts and sodium hydroxide, sodium methoxide and potassium hydroxide as alkaline catalyst (Sridharan and Mathai, 1974; Akgun and Iscan, 2007).

Alkaline catalysts such as NaOH and KOH are the most commonly used in transesterification since their reaction is much faster than an acid-catalyzed reaction. However, if high free fatty acid (FFA) feedstock such as fryer grease is used, the reaction is then partially driven to saponification which partially consumes catalysts and creates soap. Soap resulting from saponification creates difficulty in separating the by-product, glycerol, from biodiesel, which ultimately reduces the ester yield. Although acid-catalyzed transesterification does not encounter this problem, it requires a longer reaction time, higher reaction temperature, and a corrosion-tolerant reactor. The use of a two-step acid/alkaline catalyzed trans-esterification could be more suitable to produce biodiesel from high FFA feedstock such as fryer grease.

Alcohols used in transesterification are those of short chain carbon. The most popular one is methanol mainly because it is an economical source of alcohol. Also, the reaction can proceed faster when methanol is used due to its superior reactivity [Ma and Hanna, 1999]. However, solubility of oils in methanol is low; therefore transesterification is limited by mass transfer. Ethanol, on the other hand, possesses higher solubility and reduces the effect of the mass transfer limitation. The disadvantage of using ethanol involves the strong emulsion formed during transesterification which causes difficulty in the glycerol separation process. Due to this methanol was used as bringing out the glycerol with ease is very necessary. This main objective of this work is to produce biodiesel from palm kernel oil and to evaluate the physical and chemical properties of the biodiesel produced.

The oil palm, (*elaeis guineesis Jacq)* is a monocotyledonous plant that is extensively cultivated in equatorial region of Africa, Malaysia and Indonesia. It produces the palm fruits in thorny bunches on the palm tree and each palm is capable of bearing about 10 to 50 bunches per year depending on age and specy and each bunch averages 1000 to 3000 fruits with average weight of 10-20 kg. it is the most traded vegetable oil in the world market after soya bean. A fruit has a mesocarp and endocarp. The medocarp is the pulpy layer from which palm oil is obtained while the palm kernel oil and cake are obtained by cracking the kernel, heating, roasting and pressing out the oil from the nut in the kernel. PKO has baeen produced ,characterized and evaluated by Alamu et al,. 2008; Alamu, 2007; Viele et al., 2013.

MATERIALS AND METHODS

Materials

Food grade Palm kernel oil was purchased from a local dealer. It was filtered to remove solid particles. The anhydrous methanol and potassium hydroxide (KOH) were of analytical grade.

Transesterification Procedure

KOH was mixed with methanol and was poured inside a lid which was secured tightly. The mixture was then swirled round for about 30 minutes for complete dissolution to form potassium methoxide. The potassium methoxide was then measured using a measuring cylinder at different varying ratio and mixed with palm kernel oil (PKO) with specific ratio. The mixture was then poured inside a beaker with a magnetic bar being put inside the beaker and it is then placed on the magnetic stirrer. On the magnetic stirrer is a hot plate which produces heat and can be regulated. The temperature used was 40^0C. The magnetic bar was allowed to mix together the PKO and the potassium methoxide for 1hour.

Transesterification Procedure

Initial tests showed that palm kernel oil contains low free fatty acid, hence pre-treatment to convert it to ester was not carried out. The transesterification was done by mixing Palm kernel oil with a mixture of methanol and KOH (2.4g/liter) in a processor. The mixture was stirred in a processor at 600 rev/min and 60^oC for 2 hours after which it was poured into a decanter and allowed to settle overnight so that the reaction can reach equilibrium and for the biodiesel and glycerol to form separate layers. The biodiesel was washed by mixing with distilled water in ratio 2 to 1 and stirred at 300 rpm three times. At each time the hydrated top was drained off before rewashing.

Characterization of the Palm Kernel Oil and Its Biodiesel

The fuel and physicochemical properties of the oil and its biodiesel were determined using the equipment and protocols in table 2.1.

Table 2.1 Protocols and equipment for characterization of PKO and its biodiesel

Property	Standard/Units	Equipment
Specific gravity	ASTM D1298 at 25^oC	Microprocessor controlled densimeter, Accuracy $\pm$ 0.001 kg/m^3
Cloud and Pour Points	^oC	Cloud point meter
Cold Soak	^oC	

Filtration		
Kinematic Viscosity	ASTM D426 at 40 ± 0.1 °C	Capillary Viscometer (Herzog Gmbh MP-480)
Flash and Fire Points	°C	Pensky-Martens closed cup flash tester, Kehler model k-16270
Heating Value	MJ/kg	Microprocessor controlled Isoperil oxygen bomb calorimeter model 6200.
Cetane Number		Cetane/octane number apparatus
Acid Value	ASTM D664	Metrohn test apparatus model 780 Detection limit 0.01%
		Titration
Iodine value	mgI_2/g	Titration
Peroxide value	Meq/kg	Titration
Oxidation Index	Hr	Titration
Saponification Value	mgKOH/g	Titration
Unsaponifiable Matter	%	Centrifuge
Phosphorous	%	
Sulphur	%	Horiba sulphur-in-oil analyser, Model SLFA-20
Copper strip corrosion test	Scale of 5	Copper strip corrosion bath
Distillation characteristics	°C	Reduced pressure distillation apparatus.
Fatty acid profile	Wt %	Gas chromatography/Mass Spectometer
Free Fatty acid	Wt % (oleic)	Gas chromatography/Mass Spectometer
Methanol	Wt %	Gas chromatography/Mass Spectometer
Free glycerine	Wt %	Gas chromatography/Mass Spectometer

Engine testing layout

The performance of the biodiesel evaluation in a one cylinder direct injection diesel engine, which was coupled to an electric dynamometer. An additional extra fuel tank for the biodiesel was connected directly to A fuel gauge that consists of a glass tube containing four knife-edged spacers which were arranged to calibrated the volume of fuel between them. The tanks containing the biodiesel and diesel fuel were connected to the guage.

Engine Test Bed Specification

The engine test bed consists of a Lister 8/1 VA low speed single cylinder diesel engine that is connected to an electrical dynamometer by means of a multiply v- belt.
The engine is water cooled, naturally aspirated and uses a single injector.
Bore: 114.3 mm
Stroke 139.7 mm
Swept volume 1.433 litres

ISSN 2056-5860

Electrical Dynamometer

The electrical dynamometer consists of separately excited d.c. motor mounted on trunions. A dead weight of 100 N is hung on the torque arm of length 200 cm. The torque is measured by a spring balance reading and the torque absorbed is the difference between the balance reading with the machine at rest and that observed when motoring the engine.

Engine Test Procedure

The engine was initially warmed up on diesel fuel at full throttle opening for about 60 minutes so that the engine oil pressure and coolant temperature reach operational level. The test procedure is as reported by Bello and Agge (2012).

RESULTS AND DISCUSSION

The results obtained after characterization of the raw oil and its biodiesel are shown in table 4.2 and further discussion on the topic refers to it.

Table 4.1: Fuel properties of palm kernel oil and its biodiesel

Property	**Unit**	**Palm kernel oil**	**Biodiesel**	**Protocol**
Specific gravity	-	0.94	0.91	-
Cloud point	^oC	25	5	ASTM 2500
Pour point	^oC	20	10	ASTM 2500
Cold flow Filtration	^oC		80	ASTM D93
Kinematic velocity	mm^2/s	33.10	4.12	-
Flash point	^oC	242	120	
Fire Point	^oC	251	277	ASTM D445
Lower Heating Value	MJ/kg	38.2	39.3	
Cetane Number	-	60	70	ASTM D93
Iodine Value	mgI_2/g	16	65.09	-
Peroxide Value	Meq/kg	7	9	-
Oxidation Index	Hour	6	12	-
Free Fatty Acid	% (oleic acid)	0.95	1.2	-
Acid Value	mgKOH/g	0.95	1.2	ASTM D664
Saponification Value		216	226	-
Unsaponifiable Matter	%	1.25	12	-
Moisture Content	ppm	0.23	315	ASTM D2709
Sulphur Content	%	13.6	1.421	ASTM D5453
Phosphorus	%	0.005	8.11	-
Free Gyceride	%	0.36	0.040	-
Methanol Content	%	0.001	0.088	-
Copper Strip Corrosion (At 3hr, 50^oc)	scale of 5	3	2	ASTMD130

Specific Gravity

The specific gravity of the oil and biodiesel are 0.94 and 0.92 respectively. Biodiesel is lighter than the oil which will promote atomization and confer lower viscosity.

Cloud Point, Pour Point and Cold Flow Filtration

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 unfavourable cold temperature behavior. The cloud point of PKO and PKO biodiesel is 20 and 10^{0}C respectively and pour point of PKO and PKO biodiesel are 25 and 5^{o}C respectively. The pour point and cloud point of palm kernel oil reduces on transesterification.

Cold Filter Plugging Point

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 80 ^{o}C which is higher than the ambient temperature.

Kinematic Viscosity

Kinematic viscosity is a measure of a fluid’s resistance to flow. The greater the viscosity, the less eadily 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 oil and its biodiesel are 33.10mm^{2}/s and 4.12mm^{2}/s respectively. The palm kernel biodiesel viscosity obtained showed 65% reduction from the kinematic viscosity of palm kernel oil thus enhancing biodiesel fluidity.

Flash Point

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. PKO has a flash point of 242^{0}C and the value of its biodiesel is 120 ^{o}C are higher than diesel fuel. The flash point of PKO decreases after transesterification showing that the volatile characteristics has improved thereby making it more volatile.

Fire Point

It is the temperature at which the vapour produced by that given fuel will continue to burn for at least 5seconds after ignition by an open flame. At the flash point, a lower temperature the fire point of PKO and its biodiesel are 251 and 277^{0}C respectively meaning that they have high fire point and the fire point of the biodiesel is greater than the oil which is due to transesterification. It makes the biodiesel fire point higher than the higher point of diesel which is 68^{0}C.

Lower Heating Value

This is the amount of heat released when a given weight of the fuel is burnt. The lower heating value of the oil is usually lower than that of diesel because of the oxygen content which has smaller heating value and occupies about 10% of the total volume. The heating value of the oil was 38.2 and 39.3 kJ/kg for the biodiesel as against 47 kJ/kg for diesel. This is responsible for the lower torque output and higher specific fuel consumption of biodiesel (Bello, 2011).

Cetane number

Cetane Number (CN) is a measure of the ignition quality of diesel and biodiesel fuels. The CN increased from 60 for the oil and to 70 for the biodiesel. 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)

Iodine Value

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 PKO and its biodiesel respectively are 16 and 65.09mgI_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 iodine value hence saturation, increases during transesterification. 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.

Peroxide values and Oxidation index

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 increased from 7 to 9 for the oil and biodiesel respectively. 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). Once oxidative instability is initiated, it increases according to the peroxidation chain mechanism (Focke et al., 2010). Oxidation can be caused by several factors that includes, water content, presence of heat and oxygen, leading to the breakdown of unsaturated fatty acids and the formation of primary oxidation products such as hydroperoxides and conjugated dienes (Arisoy, 2008) The oxidative index increased from 6 to 12 hours after transesterification.

Free Fatty Acids (FFA)

It is the amount of KOH required to neutralize 1g of fat and expressed as mgKOH/g. It was determined by titrating with 0.01 N potassium hydroxide for the mixture of tested fuel and chemical reagents until the appearance of color pink (Bello and Agge, 2012). The free fatty acid values for PKO and its biodiesel are 0.95% and 1.2 %oleic acid respectively. Transesterification process will not occur fully if the FFA in the PKO is above 3%.

Saponification Value

Saponification value represents the number of milligrams of potassium hydroxide required to saponify 1g of fat. It is a measure of the average molecular weight (or chain length) of all the fatty acids present. Saponification value is used in checking adulteration (Ibeto et al., 2011). The high saponification values obtained for PKO indicates high presence of fatty acids which might lead to soap formation. PKO and its biodiesel have saponification values of 216 and 226 mgKOH/g respectively thereby indicating the presence of high fatty acids in the PKO and its biodiesel. These values are high for vegetable oils hence PKO is widely used for soap production as it lather very well and confer hardness to soaps. Soap inhibits the separation of biodiesel and glycerin fraction (Madras et al., 2004) and should be reduced if reasonable biodiesel yield is to be achieved. High amount of soap can result in irregular combustion and thick exhaust smoke but would also increase the cleanliness of the fuel internal components and reduce friction between rubbing parts.

The unsaponifiable matter

This is the matter remaining when the oil has been saponified. It was 1.25% for the oil and 42% for the biodiesel, which is somehow high compared tto the average for vegetable oils. Unsaponifiable matter in the vegetable oils are a variety of nonglyceride bioactive substances made up of mixtures of hydrocarbons, aldehydes, ketones, alcohols, sterols, pigments, and fat-soluble vitamins that may occur naturally or may be formed during processing or degradation of oils (Badifu, 1991).

Moisture Content

This is the water moisture in the fuel. The moisture content increased from 0.23 to 315 ppm for the oil and biodiesel respectively. High water moisture content in the oil can inhibit the transesterification process. Excess water can lead to corrosion and provides an environment for the growth of microorganisms. The existence of water in liquid fuel enhances its hydrolysis, induces the formation of microorganisms resulting in the deterioration of the fuel characteristics, particularly for biodiesel. In a diesel engine, high water content can damage fuel filter element, and cause water accumulation which at subzero temperature can form ice and block fuel flow.

Free Glycerine

Glycerol is a trihydric alcohol (containing three-OH hydroxyl group) that can combine with up to three fatty acids to form monoglyceride, diglyceride and triglyceride depending on the number of fatty acids combined.

Total glycerol = bound glycerol + free glycerol

Free Glycerol is the amount of glycerol remaining in the biodiesel after water washing. Although largely removed during water washing because it is insoluble in biodiesel, a small amount would however, remain suspended in the biodiesel. When the amount is high, it will settle at the bottom of the tank in viscous form which can block filters and course irregular combustion in the engine. Free glycerol in the oil was 0.36%, it reduced to 0.04% for the biodiesel.

Methanol

A small amount of methanol will remain in the biodiesel after water washing. Excessive methanol can reduce lubricity, reduce flash point due to its high volatility, distort the operation of the injectors and is not compatible with some materials in the fuel system. The oil contained 0.001% and biodiesel 0.088 %.

Copper strip corrosion

The PKO has a value of 3 and biodiesel 2 on a scale of 5. This study is important as some fuel system components are made from copper and its alloys which makes them susceptible to corrosion on exposure to biodiesel.

Sulphur

The oil contained 13.6% sulphur and decreased to 1.421% after transesterification Sulphur is desirable in fuel as it contribute to reducing friction but when airborne as so_2 can cause acid rain and result in soiling of the environment.

Phosphorus

Phosphorous increased from 0.005% in the oil to 8.11% in the biodiesel. High value can affect the rare metal in catalytic converter of exhaust systems.

Distillation Characteristics

The distillation characteristic has an important effect on their safety and performance of the fuel. The distillation characteristic which is also the volatility characteristic gives important information on the composition, properties and behavior of fuel during storage and use. It is the tendency of the oil to produce potentially explosive vapors. It affects the rate of evaporation.

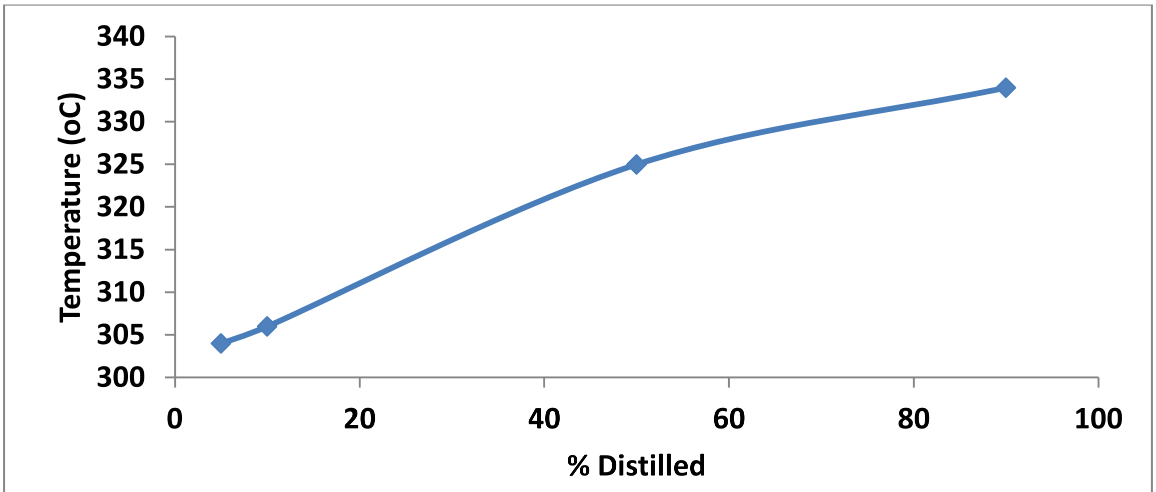

Fig. 1: Distillation Characteristics of PKO Biodiesel

The distillation characteristics of PKO biodiesel for different recovery temperatures are shown in Fig. 1. The rate of distillation is fairly uniform which shows that the volatile and heavy components of the biodiesel are fairly evenly distributed.

Chromatography Analysis

The result of the chromatographic analysis is shown in Fig 4. Lauric acid ($C_{12}H_{24}O_2$)in the oil constituted about 48.2 wt % with a molecular weight of 200, melting point of 43.6^{o}C and boiling point of 304^{o}C. Myristic acid ($C_{14}H_{28}O_2$) in the oil constitutes 20 wt% with a molecular weight of 228, melting point of 62.9 ^{o}C and 349 ^{o}C boiling point. Both are saturated and the oil has a total saturation of 87.7 % and the biodiesel 97.13%. Like coco nut oil, it is sometimes called lauric oil because of the high concentration of lauric acid in it. It is indispensible in soap making as good soap must contain at least 15% lauric acid for quick lathering. It confers hardness, solubility and a feel of quality to soap (Abigor et al., 200). Being highly saturated, the molecules are more compact and would normally be solid at room temperature.

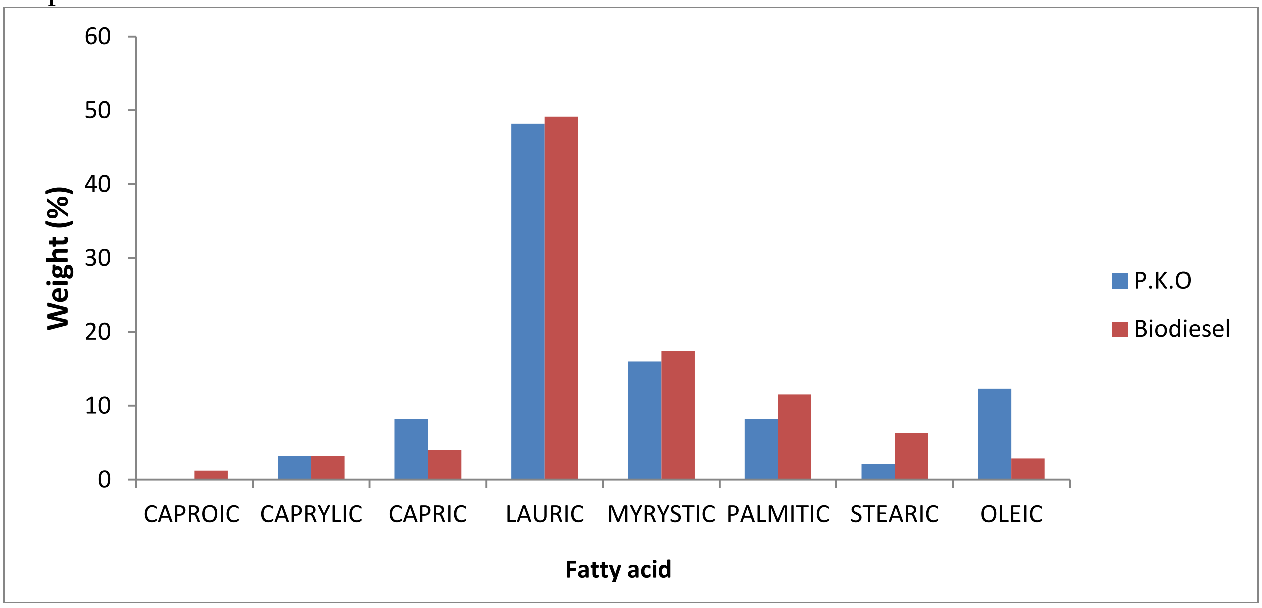

Fig. 2: Fatty acid profile of PKO and its biodiesel

ISSN 2056-5860

ENGINE TESTING

Engine Torque

The variation of torque developed at various engine speeds is shown in Fig.3. At low load, the engine speed was at the maximum, however, as the load was increased, the speed reduced. The biodiesel is able to carry more load than diesel and run smoothly up to 1600 rpm as against 2000 rpm for diesel fuel. The reason for this is the higher cetane number and about 10% oxygen content both of which ensures that the fuel burns more completely and to a much lower engine speed than can be obtained when using diesel fuel

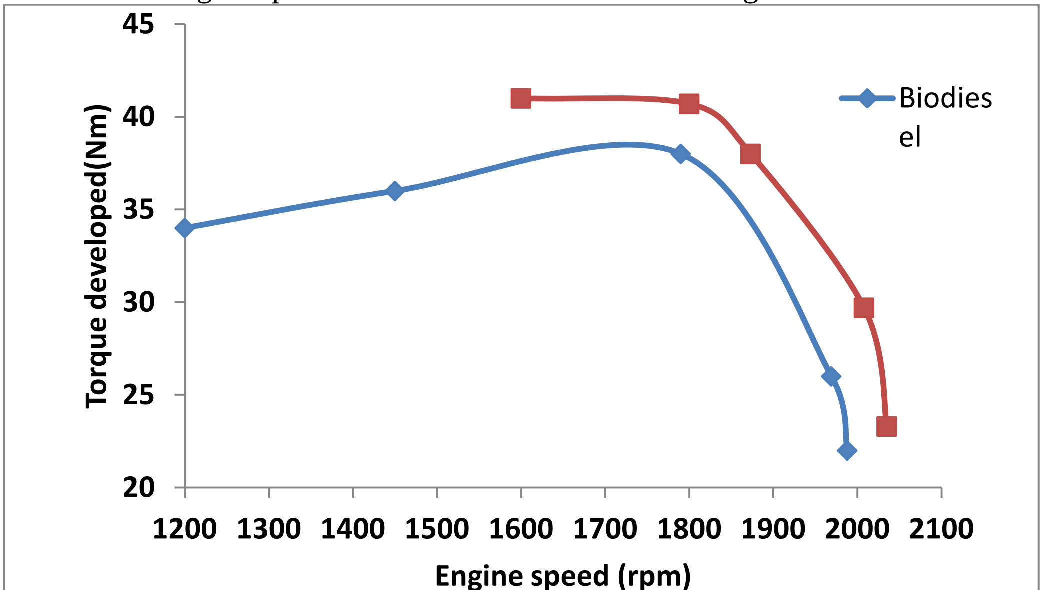

Fig.4: Variation of torque with engine speed

Specific Fuel Consumption

The specific fuel consumptions when using diesel and when using biodiesel are shown in Fig.4. The fuel consumption when using biodiesel is about 10% more than that of diesel and is consistent with the difference in their heating values. Fuel consumption increased as the speed was increased thus indicating that fuel consumption is more speed sensitive than load and the minimum fuel consumption occurs at 1800 rpm.

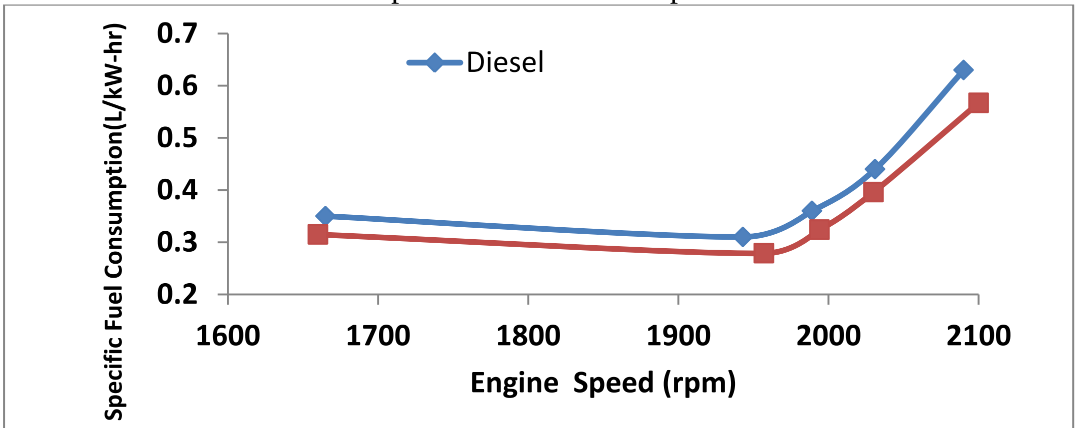

Fig.4c Variation of Specific Fuel Consumption with Engine Speed

CONCLUSION

During the investigation, it was confirmed that PKO biodiesel may be used a resource to obtain biodiesel. PKO can be 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 such as viscosity, pour point are comparable to that of diesel thereby making it feasible as a means of alternative fuel for diesel engines.

REFERENCES

Abigor R.O., T.A. Folgia M.J. Hass; J.U. Obubuzer and P.O. Uadia, (2000). Lipase catalyzed production of biodiesel from some Nigerian lauric oils. Biochem society pp. 979-980.

Anastopoulos, G.; Zannikou, Y.; Stournas, S.; Kalligeros, S. (2009), Transesterification of vegetable oils with ethanol and characterization of the key fuel properties of ethyl esters. Energies 2, 362–376.

Antony Raja,S D. Robinson smart; and C.Lindon Robert Lee, (2012). Biodiesel production from jatropha oil and its characterization. Research journal of chemical sciences vol.1 (1)pp. 81-87.

Akgun and Iscan, (2007). Effects of process variables for production of biodiesel by transesterification. Latvian journal of chemistry 52(10): 875-881.

Alamu, O.J.; T.A Akintola., C.C Enweremadu and A.E Adeleke, (2008) Characterization of palm kernel oil biodiesel produced through NaOH- catalyzed transesterification process. Scientific research and essay vol.3 (7),pp 308-311.

Bello, E.I. Agge M. Bello, E. I. and Agge M. (2011) Production, Characterization and Evaluation of Castor oil Biodiesel as Alternative Fuel for Diesel Engines. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 2(3):525-530.

Canakci M.B and J. V. Gerpen, (1998): Biodiesel production via acid catalysis. Transaction os ASAE 42(5): 1203-1210.

Satyanarayan, M, Muraleedharan C, (2010) Methyl Ester Production from Rubber seed Oil Using Two-step pretreatment Process. International Journal of Green Energy 7(1):84-90.

Ibeto,CN, A.U. Ofoefule and H. C. Ezugwu, (2011) “Analytical methods for quality assessment of biodiesel from animal and vegetable oils”, Trends Applied Sci. Res., 6, pp. 537- 553.

Dorado, M.P., Ballesteros, E., de Almeida, J.A., Schellert, C., Lo hrlein, H.P., Krause R., (2002). Transesterification of karanja (pongamiapinnata) oil by solid basic catalysts.Am.soc.Agr.Bio.Eng., 45(3) 525-529.

Ladammatos, N. and Goacher, J. (1995). Equation for Predicting the Cetane Number of Diesel Fuels from their Physical Properties. Fuel 74(7): 1083-1092.

Leung, D.Y.C.; Xuan, W.; Leung, M.K.H. A review on biodiesel production using catalyzed transesterification. Appl. Energy 2010, 87, 1083–1095.

Gui, M.M.; Lee, K.T.; Bhatia, S. Feasibility of edible oil vs. non-edible oil vs. waste edible oil as biodiesel feedstock. Energy 2008, 33, 1646–1653.

Vyas, A.P.; Subrahmanyam, N.; Patel, P.A. Production of biodiesel through transesterification of Jatropha oil using KNO3/Al2O3 solid catalyst. Fuel 2009, 88, 625–628.

De Oliveira, J.S.; Leite, P.M.; De Souza, L.B.; Mello, V.M.; Silva, E.C.; Rubim, J.C.;

ISSN 2056-5860

Meneghetti, S.M.P.; Suarez, P.A.Z. Characteristics and composition of Jatropha gossypiifolia and Jatropha curcas L. oils and application for biodiesel production. Biomass Bioenergy 2009, 33, 449–453.

Ma F, Hanna MA, (1999). Biodiesel Production: a Review. Bioresource Technology 70(1):1-15.

Van Gerpen, J., B. Shanks, R. Pruszko, D. Clements and G. Knothe, "Biodiesel Production Technology", National Renewable Energy Laboratory, NREL/SR-510-36244, 1617 Cole BoulevardGolden, Colorado 80401-3393 303-275- 3000, U.S.A, 2004.

O. J. Alamu, (2007) Development and Evaluation of Palm Kernel Oil Biodiesel Fuel", Pacific Journal of Science and Technology, 8, (2), pp 212-219.

Viele, E. L.,Uyigue, L. and Chukwuma, F. O., 2013"Esterification of High Free Fatty Acid Crude Palm Kernel Oil as Feedstock for Base-Catalyzed Transesterification Reaction", International Journal of Application of Innovation in Engineering & Management (IJAIEM), 2, (12), pp 361-365.