

# Numerical Indices for the Blending of Diesel Grades and Groundnut Oil for Simple Internal Combustion Engines

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**Abstract:-** The role being played by fuel oil (diesel oil) in compression ignition engines and machines cannot be overemphasized due to its high efficiency. However, there are some flaws in its usage which give rise to environmental concern; such as emission of toxic gases like carbon monoxide, oxides of nitrogen and so on. The aforementioned gases contribute to cancer in human and lead to increase in global warming and ozone layer depletion. This has necessitated the search for an alternative eco-friendly fuel for internal combustion engine with the view to reduce the emission of gases generated by the inevitable use of diesel engine and also to increase the engine performance. The use of bio-fuels is an effective measure to substitute fossil fuels and reduce particulate matters for diesel engines. Many researchers suggest the use of biodiesel blends of between 6 to 20 percent volume of biodiesel. In this study, biodiesel which was used as the alternative fuel was produced by conversion of the groundnut oil through alkali-based transesterification with potassium hydroxide (KOH) as catalyst. The blending was carried out in the following percentage by volume of the biodiesel 10 percent, 20 percent, 30 percent and 100 percent corresponding to B10, B20, B30 and B100 respectively. Experimental analysis was carried out using biodiesel blends and the characterization of the blend was tested for properties such as: specific gravity (density), flash point, viscosity, and so on, the results compared with available standards. The density was found to be between  $830.9\text{kg/m}^3$  and  $867.4\text{kg/m}^3$ , the viscosity falls within  $1.76\text{mm/s}^2$  and  $2.1\text{mm/s}^2$  while the flash point was between  $60^\circ\text{C}$  and  $160^\circ\text{C}$ , increasing as the quantity of biodiesel increases. The results of the blends show that the biodiesel blend B30 can be used without altering the engine configuration.

**Keywords:** Biodiesel, Alkali-Based Transesterification, Potassium Hydroxide (KOH)

## I. INTRODUCTION

The world today is in constant need of energy. As national and global economies grow, so does the need for energy increases. Electricity, solar, hydro and nuclear energy are some of the energy sources constantly explored to meet this energy demands. Machines and turbines are used to convert naturally available energy to useful work. Petroleum and natural gas, however, accounts for a sizeable chunk of the energy used around the world. Prime movers mostly use gasoline and diesel, though, other petroleum by products like aviation fuel also play an important role in meeting the world energy need. Modern economic globalization would be impossible without the ability to move billions of tons of raw materials and finished goods round the continents and to fly at speeds approaching the speed of sound. Neither steam engines nor gasoline-fuelled engines could have accomplished comparable feats. Diesel engines have made ocean shipping the cheapest mode of long-distance transport and without gas turbines would not have provided fast, inexpensive, mass-scale intercontinental travel (Vaclav, 2007).

Allen, Watt, Ackman and Pegg (1999) said that diesel is one of the most important fuels in the global economy currently. Diesel engines are the workhorse of the global economy, contributing to improved quality of life, food production, mobility and public safety. Putting it into perspective, in Nigeria alone, diesel-powered trucks, trains, ships and intermodal systems moved mostly 90 percent of the nation's freight tonnage. 'The diesel technology moves more than 80 percent of all cargo in the U.S. and more than 90 percent throughout the world. Diesel power provides two-thirds of the energy for machinery on America's farms. Diesel also powers most of the heavy equipment used in construction. Diesel is the dominant fuel source, powering 60 percent of construction equipment and using 98 percent of all energy' (Diesel Technology Forum, 2014).

At 6,500 MW, the installed capacity of Nigeria's public electricity grid is at best 30 percent of current requirements, and on average most homes have access to public electricity supply for 6 hours daily or less. Addressing electricity supply shortfalls for most Nigerians means procurement and

installation of private diesel-powered generators. Current estimates indicate that over 90 percent of businesses and 30 percent of homes have diesel-powered generators, meaning that there are currently about 15 million generators in use in Africa's most populous nation (Awofeso, 2011). The agricultural sector and agro allied industries are also powered by diesel powered engines. A look around any construction environment will show diesel powered trucks and other earth moving equipment being used. All of these show that the place of diesel in our economy cannot be overemphasised.

Despite the benefits of diesel, it has its flip side. Diesel exhaust contains more than 40 toxic air contaminants, including many known or suspected cancer-causing substances, such as benzene, arsenic, and formaldehyde (Awofeso, 2011). Diesel engines are major contributors of various types of air polluting exhaust gases which include particulate matter (PM), carbon monoxide (CO), oxides of Nitrogen (NO<sub>2</sub>) and other harmful components (Oguzhan, 2013). In relation to human health, it is estimated that up to 70 percent of cancer risk attributable to inhalation of toxic air pollutants in the United States arise from diesel exhaust. Exposure to diesel exhaust has been linked to lung cancer in occupational settings. In Nigeria, indirect evidence of the impact of diesel exhaust on lung cancer is indicated by its rising incidence among urban-based non-smokers less than 60 years old, most of whom use diesel generators on a daily basis. Regional surveys suggest that Nigeria's asthma prevalence among adults increased from 5.1–7.5 percent in 2003 to 13.1–14.2 percent in 2006, and Nigeria currently has the highest prevalence of asthma in Africa, after South Africa (Awofeso, 2011).

Therefore, there arises the need for a clean diesel technology that will reduce the level of harmful emissions to the environment. It has been demonstrated that the formation of these air pollutants can be significantly reduced by incorporating or blending diesel grade with biofuel for the development of the alternative fuels for internal combustion engines in order to reduce harmful gaseous emission which is a major environmental concerns worldwide. Among these alternative fuels, biodiesel has received much attention in recent years for compression ignition (diesel) engines (Al-Hassan, Mujafet and Al-Shannag, 2012).

Biodiesel is a renewable energy source which can be produced from vegetable oils and animal fats, and act as alternative fuel. It has numerous advantages over conventional fossil fuel (Mahajan, 2014). These advantages include, low idle noise and easy cold starting, when added it reduces engine wear thereby increasing the life of the fuel injection equipment, thus, saving cost (Bamgboye, 2013).

For now, biodiesel is the commonly accepted biofuel and act as a substitute for diesel fuel in internal combustion engines (Irina, Sibel, Anisoara and Elis 2013). Thus, it plays a critical role in human existence as many countries in the world are more concerned about how to control the global increase in the price of fossil fuel and its effect on the

environment. Biodiesel can be replenished by farming, while fossil fuels come from underground deposits of hydrocarbons which cannot be renewed (Bello and Fatimehin, 2015).

The prospect of an agricultural based crop such as groundnut as a source of alternative fuel for internal combustion engine would to a large extent, reduced the overdependence on fossil fuel. Being classed as a good feedstock for biodiesel production, groundnut oil has continued to receive increased interest because it can be produced from renewable sources. More so, its greatest advantage is established in the fact that its property as a fuel is compatible with diesel fuel. The compatibility of these properties enables the Blending of a Biodiesel and diesel grades.

This research will address many topics involved in the determination of biodiesel fuel efficiency including which properties best describe a viable fuel, how these properties relate to fuel efficiency and which methods are best to determine the quantitative values of these properties. Thus, several properties can be used to determine the efficiency of biodiesel as an alternative fuel for internal combustion engine, this includes: cetane index, heat of combustion, flash point and so on (Jason, 2014).

In this study, numerical indices for blending of Diesel grades and groundnut oil based biodiesel for use in Internal Combustion Engine was evaluated. This evaluation involved procedures designed to mix biodiesel and commercial fuel in order to meet the specification required for personal or industrial consumption. The mixing and combining of hydrocarbon fractions, additives, and other components to produce finished products with specific performance properties is beyond estimating only the physical properties, it must also be done on a volumetric basis (Senticumar, 2011).

The use of vegetable oil as alternative fuel was long demonstrated by Dr. Rudolph Diesel in 1912, when peanut oil was used on engine instead of conventional fuel. Since, then, various researches had taken place on improving the usage of this oil in a reciprocating engine. One common method of generating biodiesel from groundnut involves crushing, reaction with catalyst, flow analysis and performance testing. The use of crude form of groundnut oil in an engine creates operational and durability problems in direct injection diesel engine because of its high viscosity and low volatility. Transesterification, blending and pre-heating groundnut oil with other fuel has been identified to re-adjust some of its property that leads to problem which occurs as a result of its independent use (Sankaranarayanan, 2010).

The outcome of this blend are at most times positive except the cost of synthesizing vegetable oil which adds to the cost of blending biodiesel with diesel (Uzama, 2011). For now, biodiesel is the commonly accepted bio fuel as a substitute for diesel fuel in internal combustion engines. Diesel fuel blends with up to 20 percent biodiesel can be

used in diesel engines without any modification (Irina et.al, 2013). The overall objectives of the study is to determine numerical indices for the commercial production of a blend of petroleum diesel grades and groundnut oil to obtain a biodiesel with comparable performance output to the conventional petroleum diesel but with less to non-environmental polluting effects of the latter.

## II. REVIEW OF RELATED LITERATURE

According to Jon (2005), diesel engines provide choice for heavy duty application in agriculture, construction, industrial and on-highway transport for more than fifty years. He believes that this early popularity may be attributed to its ability to use the portion of the petroleum crude oil which had previously been considered a waste product from the refining of gasoline. He maintained that the operating principles of diesel engines are significantly different from those of the spark-ignited engine. Thus, in an internal combustion engine, combustion of fuel takes place inside the engine cylinder as a result of applying ignition to correct mixture of proportion of air and fuel (Khurmi and Gupta, 2010). Diesel engine only achieves its ignition when air supplied is compressed to a very high pressure. However, fuels which are burn in a combustion engine were burnt to release heat. As such, liquid fuels are considered as an excellent energy source for reciprocating engine. Liquid fuels are easy to burn and have nearly constant heating values, and are mixture of hydrocarbon compounds which are liquid at Standard Temperature and Pressure (Nag, 2008).

The main combustible elements in fuel are carbon, hydrogen and sulphur. To release heat, combustion of fuel would normally depend on physical and chemical factors. The chemical factors are those which relate to the temperature and concentration of the reactants as determine by the kinetics of chemical reaction at play during combustion. Experiment to establish the chemical perspective on fuel indicated that to achieve highest efficiency and lowest emission, optimizing fuel system is required. Thus, primary performance of combustion engine fuel is mostly defined by the fuel's octane number and cetane numbers (Wallington, 2006).

In recent time, considerable effort devoted to improving engine efficiency and lowering emission have been achieve through mechanical and computerized control of the combustion process. Since fuel kinetics determines the ignition, fuel structure effects therefore become significant for ignitability. The ignitability relating to fuel octane or cetane number therefore indicate that opportunity exist for an optimally formulated fuel for advanced engines. According to Wallington (2006), changes in fuels will be more of evolution rather than revolution, which will lead to modifying the chemical composition of fuel while the broad composition will remain. For instance, Gas to Liquids (GTL) and Biomass to Liquid (BTL) technology.

One of such near future possibility is that of Ammonia as fuel for internal combustion engine. Ammonia based fuel generated from biomass gasification is established to enable zero carbon emission (Brohi, 2014). According to Oniya and Bangboye (2013), the performance of groundnut ethyl ester blended with diesel in a compression ignition engine will generate the same values of torque, speed and exhaust gas temperature as the use of Diesel oil. The practice of using fuel from a plant source remains one of the largest available options for fuel evolution.

### ➤ *Production of Biodiesel and Fuel Blending:*

In obtaining biodiesel, the vegetable oil or animal fat is subjected to a chemical reaction termed transesterification (Gerhard, 2014). The vegetable oil or animal fat is reacted in the presence of a catalyst which is usually the base with an alcohol, usually methanol to give the corresponding alkyl esters. Biodiesel can be produced from a great variety of feedstock, which includes most common vegetable oils such as soybean, cotton seed, pal, peanut, coconut etc. The choice of feed stock depends largely on geography, that is, depending on the origin and quality of the feed stocks and changes in production process.

The advantages of biodiesel as compared with petrodiesel (Gerhard, 2014) include: derivation from a renewable domestic resource, thus reducing dependence on preserving petroleum, reduction of most exhaust emissions, higher flash point leading to safer handling, storage and excellent lubricating. The suitability of biodiesel as a fuel depends to a large extent, properties such as heat of combustion, pour point, cloud point, viscosity, oxidative stability and lubricating. In the present study, most of these properties have been analysed in order to know the suitability of the biodiesel for diesel fuel. Ojolo and Sobamowo (2012) presented a method for the production of Bio-diesel from palm kernel oil and groundnut oil. The trans-etherification process yielded ninety eight percent conversion of groundnut oil to biodiesel while the density was found to be 850.8kg/m<sup>3</sup>, all of which point to the fact that biodiesel can successfully power a diesel engine.

Beg (2010) used blending as part of the process of production of Diesel fuel from used engine oil. Accordingly, recovering diesel fuel from waste oil was able to solve problem experienced during scarcity and production. This implies that blended fuel sample was cleaner and has good lubricity as well as low acidity. Quality of mixing certain percentage of Biodiesel with Diesel was further examined and found that adopting best recipes of a mixture would ensure optimal condition of blend. While there might be a possible option to blend mixture optimization, a numerical simulation of blend combustion indicated that mixture fraction of elements are inaccurate because of their substantially different composition and heating values (Muhammed, 1999).

Jason (2014) used several chemical properties to determine a best fuel between sewage sludge and canola oil. The properties compared included cloud point, pour point, specific gravity, viscosity, distillation range, cetane index,

flash point, heat of combustion, water and sediment, ash, carbon residue, and elemental analysis. The research shows that all the physical properties associated with biodiesel are intertwined and that the difficulty in interpreting these results comes mostly in understanding the relationships between the values. According to this study, biodiesel shows great potential as an alternative fuel source as it mirrors many of the key chemical properties of diesel. The latter study also claimed that sewage sludge in canola oil biodiesels were negligible in most cases.

- *Analytical Methods for Biodiesel:*

In the study carried out by Gerhard (2014), it was reported that during the transesterification process, intermediate glycerol, mono- and diacylglycerols, are formed, small amounts can remain in the final biodiesel (methyl or other alkyl ester) product. In addition to these, partial glycerol, unreacted triacylglycerols as well as unseparated glycerol, Free Fatty Acids (FFA), residual alcohol, and catalyst can contaminate the final product. These contaminants can lead to severe operational problems when using the biodiesel, namely, engine deposits, filter clogging, or fuel deterioration. It was therefore recommended that standard should be used when using biodiesel for heating oil purposes to limit the amount of contaminants in biodiesel fuel. Under these standards, restrictions are placed on the individual contaminants by inclusion of items such as free and total glycerol for limiting glycerol and acylglycerols, flash point for limiting residual ash value for limiting residual catalyst.

Komers, Stloukal and Machek (1998) investigated some methods used in the analysis of biodiesel, including procedures for determination of contaminants such as water and phosphorus. They concluded that the determination of fuel quality is an issue of great importance to the successful commercialization of biodiesel, and that continuously high fuel quality with no operational problems is a prerequisite for market acceptance of biodiesel. To meet the requirements of biodiesel standards, the quantitation of individual compounds in biodiesel is not necessary but that the quantitation of classes of compounds is essential. That is, in the determination of mono-di - or triacylglycerol, it does not matter which fatty acid(s) is attached to the glycerol backbone. However, for the determination of total glycerol, that, it does not matter which kind of acylglycerol (mono – di – or tri) or free glycerol the glycerol stems are as long as the limits of the individual acylglycerol species or free glycerol are observed.

The above researches also maintained that all methods used in the analysis of biodiesel are suitable with appropriate modification for all biodiesel feed stocks and that the ideal analytical method would reliably and inexpensively quantify all contaminants even at trace levels with experimental ease in a matter of seconds at most, or even faster for online reaction monitoring. In their opinion, they emphasised that no current analytical method meets these extreme demands, and that compromises are necessary when selecting methods for analysing biodiesel or monitoring the transesterification reaction. In addition, they

stated that the increase in the use of blends of biodiesel with conventional, petroleum based diesel fuel, leads to the detection of blend levels that is rapidly becoming another important aspect of biodiesel analysis. Thus, in this study, analysis were carried out as prescribed by Ofomatah, Ezema and Idoko (2015) where individual parameters are investigated, since these parameters are important to the final quality of biodiesel and its blends.

- *Experimental Analysis of Biodiesel:*

Dunn, Shockley and Bagby (1996), worked on the new term approaches for improving the low temperature properties of triglyceride oil derived fuels for direct-injection compression ignition engines. This work explores two near term approaches for improving low temperature flow properties of methyl esters. The first approach, winterization, involves equilibrium a quiescent mixture of methyl esters at a temperature between its cloud point and pour point. The second approach involves treatment with off-the shelf cold flow additives. Results showed that additive treatment affect the cloud point or viscosity. Ale (2003) presented that, every engine is designed for a particular fuel and any change in fuel composition may affect the engine performance.

Kerosene has been blended with petrol and diesel separately. Fuels mixed in different proportions were allowed to run at low engine idling speed. The carbon monoxide emission varied from 0.15 percent to 0.23 percent and unburned hydrocarbon from 260 revolution per minutes (rpm) to 435 rpm respectively when proportions of kerosene in petrol was increased. Murai, Kishor and Reddy (2006) investigated the exhaust emissions from a single cylinder spark ignition (SI) engine with kerosene blended gasoline with different versions of the engine, such as conventional engine and catalytic coated engine with different proportions of the kerosene ranging from 0 percent to 40 percent by volume in steps of 10 percent in the kerosene-gasoline blend. They also worked on improving the performance of compression ignition engine using biodiesel prepared from pongamia, jatropha and neem oil.

Bello and Agge (2012) in their study maintained that groundnut oil can be converted to methyl esters and when the various properties were compared to standard values as obtained from ASTM, it was established that they were within the limits for biodiesel. It was suggested that since the pour point from their study was found to be 6°C, it cannot be used when the temperature fall below this value. It was also found from the study that the cetane number is just above the maximum for biodiesel. It was concluded that based on the similarity of the properties with the standard values, it can then be used as alternative fuel for diesel engines.

In a related study by Bello and Fatimehin (2015), biodiesel was produced from raw groundnut oil through alkali catalysts transesterification using methanol in the presence of KOH. The results obtained as shown in Table 1

was compared with that of standard values and the Authors concluded that, it can be used effectively in diesel engine as alternative fuel.

Table 1 Properties of Groundnut Oil and its Methyl Ester

Property	Unit	Groundnut Oil	Groundnut Oil Biodiesel (methyl ester)	ASTM limits D6751	EN limits 14214
Specific gravity at 15°C	Kg/m <sup>3</sup>	0.97	0.92	0.860-0.900	0.860-0.900
Pour point	°C	4	3	-	-
Cloud point	°C	7.5	8	-	-
Flash point	°C	178	132	130 min	120 min
Fire point	°C	252	294	-	3.5-5.0
Kinematic Viscosity at 40°C	mm <sup>2</sup> /s	37.8	4.4	1.9-6.0	-
Heating value	MJ/kg	38	39.8	-	-
Cetane index	-	-	59.85	47 min	-
Iodine value	mgI <sub>2</sub> /g	82.36	71.8	120	6 min
Peroxide value	mea/kg	20.25	4.00	-	120 max
Oxidation index	Hours	6	10	3 min	-
Saponification value	mgKOH/g	191.32	184	-	-
Unsaponifiable matter	%	-	37	-	-
Free fatty acid	% oleic acid	1.84	0.7	0.05 max	-
Acid value	mgKOH/g	3.7	0.8	0.05 max	360 max
Water and residue	Wt %	0.09	0.05	-	-
Moisture content	Vol %	151.1	310	-	-
Cold soak filtration	°C	-	82	0.05%	-
Sulphur	Wt %	12.9	1315	-	-
Phosphorus	Wt %	3.4	11.44	No.3 max	-
Copper strip corrosion	Scale of 5	-	3	-	-
Free Glycerine	Vol %	-	0.037	-	-
Glycerine					
Methanol	Vol %	-	0.084		

Source: Bello and Fatimehin, 2015

Ramaraju and Ashok (2011) worked on production of biodiesel using punakka oil. The biodiesel was produced using two stage process, first by acid and then alkaline esterification. The acid value of the oil was reduced by acid esterification. The product from this stage was subjected to alkaline esterification to produce biodiesel. The various parameters like reaction temperature, catalyst concentration and reaction time were established. The properties were closer to that of Biodiesel. Martin and Prithviraj (2011), worked on the performance of compression ignition engine

using blends of the cotton seed oil with diesel combustion engine. Performance, emission and combustion parameters were calculated at various loads using blended biodiesel and compared with the neat diesel. The 60% blend of biodiesel with the conventional diesel fuel gives the maximum efficiency and reduction in smoke or reduction in carbon monoxide and hydrocarbon emissions. Thus, most of the test carried out were compared with data on fuel specification (Technical bulletin) for biodiesel blends of B6-B20 and B100 (Tables 2 and 3) as related to ASTM (2012).

Table 2 Fuel Specification (Minimum Requirement) US Biodiesel Blends According to ASTM D7467-10 (B6-B20)

Properties	Units	Limit values ASTM D 7467	Test method
Biodiesel content	% (V/V)	6-20	ASTM D7371
Flashpoint	°C	Min. 52	ASTM D93
Water and sediments	% (V/V)	Max. 0.05	ASTM D2709
Kinematic viscosity at 40°C	mm <sup>2</sup> /s	1.9 – 4.1	ASTM D445
Ash content (oxide ash)	% (m/m)	Max. 0.01	ASTM D 482
Sulphur content	% (m/m)	Max 0.0015* Max. 0.05**	ASTM D 5453
Corrosion effect on copper	Degree of corrosion	No.3	ASTM D130
Cetane number		Min. 40	ASTM D613
Cloud point	°C	Report	ASTM D 2500
Coke residue	% (m/m)	Max. 0.35	ASTM D 524
Acid number	Mg KOH/g	Max. 0.30	ASTM D 664
Boiling curve at 90 vol.%	°C	Max. 343	ASTM D 86

Lubricity, HFRR at 60°C	µm	Max. 520	ASTM D 6079
Oxidation stability 110 °C	Hours	Min. 6	EN 14112
ASTM D7467 – 09a Grade S 15			
ASTM D 7467 – 09a Grade S 500			

Source: Deutz Technical Bulletin 0199-99-1218/0 EN, 2012, Appendix 8

Table 3 Fuel Specification (Minimum Requirement) US Biodiesel According to ASTM D6751-11a (B100)

Properties	Units	Limit values ASTM D 6751	Test method
Calcium and Magnesium (together)	mg/kg	Max 5	ASTM D14538
Flashpoint	°C	Min. 93	ASTM D93
Water and sediments	% (V/V)	Max. 0.05	ASTM D 93
Kinematic viscosity at 40°C	mm <sup>2</sup> /s	1.9 – 6.0	ASTM D 2709
Ash content (oxide ash)	% (m/m)	Max. 0.02	ASTM D 445
Sulphur content	% (m/m)	Max 0.0015* Max. 0.05**	ASTM D 874
Corrosion effect on copper	Degree of corrosion	No.3	ASTM D 5453
Cetane number		Min. 47	ASTM D 130
Cloud point	°C	Report	ASTM D 613
Coke residue	% (m/m)	Max. 0.050	ASTM D 2500
Acid number	mg KOH/g	Max. 0.50	ASTM D 4530
Content of free glycerine	% (m/m)	0.020	ASTM D 664
Content of total glycerine	% (m/m)	0.240	ASTM D 6584
Phosphor content	% (m/m)	Max. 0.001	ASTM D 6584
Boiling curve at 90 vol. %	°C	Max. 360	ASTM D 4951
Sodium and potassium (together)	mg/kg	Max. 5	ASTM D 1160
Oxidation stability 110 °C	hours	Min. 3	EN 14112
ASTM D7467 – 09a Grade S 15			
ASTM D 7467 – 09a Grade S 500			

Source: Deutz Technical Bulletin 0199-99-1218/0 EN, 2012, Appendix 9

#### ➤ Basic Physical Properties of Biodiesel:

##### • Viscosity of Biodiesel:

Gerhard (2014), described viscosity as a means of measure of resistance to flow of a liquid due to internal friction of one part of a fluid moving over another. The atomization of a fuel upon injection into the combustion chamber is affected by viscosity which leads to the formation of engine deposits. The higher the viscosity, the greater the tendency of the fuel to cause such problems, and the viscosity of transesterified oil (i.e biodiesel) is about an order of magnitude lower than that of the parent oil.

High viscosity is the major fuel physical property that explained why raw vegetable oils have largely been abandoned as an alternative diesel fuel (DF). However, kinematic viscosity ( $\nu$ ), which is related to dynamic viscosity ( $\eta$ ) by density as a factor is included as a specification in biodiesel standards and it can be determined by standards such as ASTM D445 or ISO 3104. Also the viscosity of diesel fuel is lower than that of biodiesel and the difference in viscosity between the parent oil and the alkyl ester derivatives could be used to monitor biodiesel production and the effect of viscosity on the blending biodiesel (DeFilippis, Giavarini, Scarcella and Surentino 1995).

Allen *et. al.* (1999) predicted the viscosity of fatty materials. The viscosity values of biodiesel/fatty ester mixture were predicted from the viscosities of the individual

components by a logarithmic equation for dynamic viscosity. They explained that viscosity increases with chain length (i.e number of carbon atoms) and with increase in degree of saturation. This holds for the alcohol moiety because the viscosity of ethyl esters is lightly higher than that of methyl esters, and factors such as double-bond configuration also influence viscosity.

Works carried out by several researchers demonstrate that the properties of blended fuel indicate kinematic viscosity of blended fuel decreases linearly with increasing temperature and increasing blending ratio of the fossil fuel (Mahajan, 2014). The temperature and blending ratio plays a major role in the viscosity of blend fuel. While little control over the working temperature of the fuel is possible, greater control on blending ratio is also achievable. The effect of temperature on viscosity is shown in Table 4: It can be seen that the kinematic viscosity at forty degrees Celsius (40°C) and for basic condition of ambient temperature greater than zero degree Celsius (0°C) the minimum viscosity is 1.8mm<sup>2</sup>/s and the maximum 5.0mm<sup>2</sup>/s while at ambient temperature less than zero degree Celsius, the minimum viscosity is 1.2mm<sup>2</sup>/s and maximum 4.0mm<sup>2</sup>/s. Thus, it is accepted in practice that any fuel with viscosity between 1.8mm<sup>2</sup>/s and 5.0mm<sup>2</sup>/s could be used in hot temperature region such as in most African countries while fuel with viscosity between 1.2mm<sup>2</sup>/s and 4.0mm<sup>2</sup>/s may be used in cold temperature regions like Russia, Iceland (Gerhard, 2014).

Table 4 Minimum Requirements for Fuels in Countries in which None of the Named Diesel Fuels Released by DEUTZ Exist

Parameter	Basic condition	Test Method	Units	DEUTZ requirement	
				Min.	Max.
Density at 15 °C	-	ISO 3675/ ISO 12185	kg/m <sup>3</sup>	820 <sup>1</sup>	876 <sup>2</sup>
Cetane number	Ambient temperatures > 0°C	ISO 5156/ISO 15195/ ASTM D613/ASTM D6890	-	40.0	-
	Ambient temperatures < 0°C			45.0	-
Kinematic viscosity at 40 °C	Ambient temperatures > 0°C	ISO 3104/ASTM D44	mm <sup>2</sup> /s	1.8	5.0
	Ambient temperatures < 0°C			1.2	4.0
Cloud point	-	-	-	Not higher than the ambient temperature	
Pour point	-	ISO 3016/ASTM D97	-	At least 6°C lower than the ambient temperature	
Sulphur content	Engine without exhaust gas after-treatment	ISO 20846/ISO 20847/ASTM D3605/ASTM D1552	%(m/m)	-	1.0
	Engine without exhaust gas after-treatment		mg/kg	-	2000
	Engine without exhaust gas after-treatment		mg/kg	-	5
Ash Content	Engines without exhaust gas after-treatment	ISO 6245/ASTM D482	%(m/m)	-	0.01
Water Content		ISO 12937	mg/kg	-	200

Source: Deutz Technical Bulletin 0199-99-1218/0 EN, 2012, Appendix 11

- *Biodiesel Lubricity:*

Lubricity is defined as the ability of a liquid to provide hydrodynamic and/or boundary lubrication to prevent friction and wear between moving parts. Lepera (2000) defined lubricity as that quality that prevents wear when two moving metal parts come in contact with each other. Thus, lubricity is the ability to reduce friction between solid surfaces in relative motion. Keith and Conley (1995) stated that the production of a cleaner diesel fuel could lower the lubricity of diesel fuel. The lubricating quality of diesel fuel dropped significantly, when the United States mandated the use of a diesel fuel that had less than or equal to 500 parts per millions (ppm) sulphur and that the petroleum industry expects the lubricity of petroleum diesel to drop even lower (sulphur <15ppm)

Viscosity of diesel fuel is related to lubricity (Lacey and Mason, 2000), in such a way that many researchers suggested that the lubricity of the fuel is not provided by fuel viscosity (Barbour, Rickeard and Elliott, 2000). It was also reported that oxygen definitely contributes to the natural lubricity of diesel fuel, but that nitrogen is more active lubricity agent than oxygen and maintained that diesel fuels that are high in sulphur but low in nitrogen exhibit poor lubricity.

These authors noted that the lowering of sulphur or aromatic contents of a substance does not reduce its lubricity. However, hydrotreating the same substance would yield a lower lubricity of the diesel fuel. Keith and Conley (1995), also explained that the components like oxygen and nitrogen may be rendered ineffective as a result of severe hydrotreatment to desulfurize the fuel. Nevertheless, it is imperative to know that some fuel injection system like diesel engines rely upon diesel fuel to lubricate their moving

parts with close tolerance under high temperatures and high pressure (Lepera, 2000).

- *Environmental Implication of Biodiesel:*

- *Emission Reduction:*

Sharp (2004) explained the importance of reducing exhaust emissions of diesel engines and how it has led to the development of new diesel engine technology which includes, (i) diesel –fuel injection technology, (ii) diesel – fuel that has been refined to higher standards. The diesel fuel injection technology of a modern diesel engine operates at higher pressure than its counterparts and has led to demand for better lubrication from the diesel fuel that has traditionally lubricated the fuel injection system of the diesel engine. However, he mentioned that the Environmental Protection Agency (EPA) in United States mandated that all its diesel fuel being sold should contain less than or equal to 500ppm sulphur in order to reduce diesel fuel sulphur content, and concluded that it was only the petroleum refineries that met this condition due to the special hydro treating of the diesel fuel .EPA (Environmental Protection Agency) further reduced the level of sulphur in petroleum diesel fuel to 15ppm or less as new standard, so as to reduce diesel – engine exhaust emissions by as much as ninety percent compared to 500ppm low sulphur diesel-fuel era. This reduction in engine exhaust emissions was projected for new diesel engines that are equipped with diesel-engine exhaust catalytic converters.

Diesel engines were mentioned as the major contributor of nitrogen oxides (NO<sub>x</sub>) and particulate matter (PM) to ambient air pollutant inventories (USEPA, 2003). However, the quantity of carbon monoxides (CO) derived from diesel engines is generally small compared with

emissions from light-duty gasoline vehicles. The effect of biodiesel on emissions from 2–stroke engine was analysed by Graboski and McCormick (1997). The effect of biodiesel on PM and NO<sub>x</sub> emission were also analysed.

- *Health Implication of Diesel and Biodiesel Option:*

Due to the Health problem being caused by diesel engines particles which cause a chronic lung cancer hazard to human, (USEPA, 2002) carried out a mutagenic potential of particulate matter to estimate the possible carcinogenic health effects. Moreover the influence of biodiesel and different petrodiesel fuels on exhaust emission and health effects was investigated by Jurgen Krahl, Axel Munack, Olaf Schroder, Hendrik Stein and Jurgen Bunger. The result shows that carbon monoxide (CO) for all fuels, the emission were clearly far below the legal limit of 4.0g/kwh valid for the engine used, while RME led to a considerable decrease in CO emissions. It was stated that this could arise because of the oxygen in the ester bonds, which allows more CO to be oxidized to CO<sub>2</sub>. For Hydrocarbon, the emission rate was shown to be far below the legal limit of 1.1 g/kWh, while RME caused a significant decrease, however, in the case of Nitrogen oxides NO<sub>x</sub>, the emission rates were stated to be below the legal limit of 7g/kwh and that they approached the limit. He demonstrated that NO<sub>x</sub> and particulate matter are the critical components of diesel engines.

Sven and Guideo (2004) explained the environmental implication of biodiesel and considered it to be environmentally friendly, CO<sub>2</sub>-neutral and biodegradable, preserves fossil fuels and that it does not cause significant sulphur-containing emissions, but that it may be valid in the case of direct combustion which yields exactly the amount of CO<sub>2</sub> that was removed from the atmosphere when cultivating the energy-yielding plants. However the whole life cycle of a biodiesel was examined during the production of biomass via conversion to use as an energy source, the results shows that there were not necessarily natural advantages. Examples given includes, in the agricultural production of rape and sunflower seeds, two important feed stocks for biodiesel, fertilizers and biocides as well as tractor fuels were said to be consumed. And that the production of these resources in turn, consumes significant amounts of fossil fuels. Another observation is being carried out on a restricted fashion for the production of soy. Also biodiesel feed stock shows that the use of fossils fuels has a connection with climate-affecting emissions, and that when considering the entire life cycle, the CO<sub>2</sub> balance is not neutral initially. CO<sub>2</sub> is included because of its effect on climate. He further stressed that, since CO<sub>2</sub> is one of the several gases that affect climate and that through the presence of other climate-affecting gases, a positive CO<sub>2</sub> balance is diminished, neutralized, or even overcompensated. The study related the case of dinitrogen (N<sub>2</sub>O; nitrous oxide; laughing gas) which arises from fertilizer production and agricultural ecosystems and which is not liberated in significant amounts in the production chain of fossil fuels.

The environmental impact of commercial production of groundnut for the blending of diesel grades such as the contamination of soil and surface water with biocides and their degradation products (i.e nitrates and phosphates) can be quantified and the ecological disadvantages of biodiesel is far lower when compared to conventional diesel grades.

### III. MATERIALS AND METHOD

➤ *Materials:*

This unveils the methods undertaken in order to successfully carry out this research work. It also includes the approach of sourcing for materials, the processes involved in biodiesel conversion and analysis. The major materials for this study were diesel grades (Low- pour fuel oil-LPFO, and High- pour fuel oil – HPFO) and the raw groundnut oil. Equipment for testing various physio-chemical properties of the blend of the above major substances include: beakers (20ml, 40ml and 100ml), pipette, separating funnel, digital weighing balance, water heater, 360°C thermometer and a thermocouple, distilled water, magnetic stirrer, filter paper, separating flask, litmus paper, methanol, koit pellets.

- *The Sources of Material:*

The groundnut oil used for this research was sourced from the open Market in Nsukka, Enugu State. This is because; the laterite loamy soil of the region yielded groundnut seeds that were bigger and contains more oil (weight per volume w/v) of the crushed seed. Besides, the extracted oil does not show any tangible reduction in viscosity when exposed to temperatures lower than 18°C (ESADP, 2015).

- *Diesel Grades for Blending:*

The diesel grades used for this study were the distillate known as automotive gasoline (AGO) used in automotive diesel engines, space heating, industrial furnace, boilers and heavy industrial plants like generating sets. These diesel grades had a kinematic viscosity of between 1.6 – 5.5 centistokes at 100°F. All the diesel grades indicated the required diesel index of 47min (NNPC, 2015). The cost of these diesel grades varies slightly.

➤ *Methods for Biodiesel Production from Groundnut Oil and Blending:*

The groundnut oil was that which was locally extracted from groundnut by the locals. Local extraction usually involves grinding the groundnut and pressing it mechanically to extract the crude groundnut oil from the crushed seed (seedcake). Though, this process usually leaves some oil in the seedcake. The left over seedcake after extraction of groundnut oil is used in producing groundnut cake (Kuli kuli) and as a constituent of livestock feed.

- *Methods for Groundnut Oil Extraction:*

The groundnut oil used for this study was obtained by first roasting the seeds in a heated frying pan at a temperature of 47°C, for about 36minutes in the medium of some quantities of cassava granuels called “garri”. Sharp sand was also fried, but the former was preferred as the groundnut residue after oil extraction was fed to domestic



animals. Both methods yielded same quantity of oil after the extractive procedure. The latter process involves dehusking the cooled roasted groundnut seeds, winnowing and crushing the lean seeds using an electric grinder. The finely grinded groundnut seed, now mashy and oily is then massaged continuously using the palms of the hand to extrude more of the oil from the grinded mash. The bulk of this material (grinded groundnut seed) was then placed in a hot bowl and heated gently between temperatures of 40 - 80°C to obtain a clear light yellowish fluid.

Roasting of groundnut seed above 47°C and longer than 36minutes would yield a dark roasted seed, whose oil appear black-yellowish with a pungent carbon-burnt smell.

A one paint container measure of the groundnut seeds with a mass of 2.1kg (21N weight) yielded 1500ml of the oil. The soxhelt extractor was not used as recommended chemicals were required to be added to the roasted groundnut seed to enhance the extractive process.

This author believes would affect the physiochemical indices of the final product that would be produced (i.e. biodiesel).

- *Degumming of the Crude Groundnut Oil:*

This was carried out by measuring 440ml of crude groundnut oil into a beaker. The oil in the beaker was then heated to a temperature of 70°C (figure 1b). 92ml of distilled water was measured into another beaker and heated to a temperature of 70°C (figure 1a). The hot distilled water was then added to the oil gradually while stirring it gently on a constant temperature magnetic stirrer (figure 1c). The mixture was stirred for 30 minutes at 70°C. The mixture was then poured into a separating flask and allowed to stand overnight (about 20 hours). The mixture separated into three layers; a water bottom layer, a gum (phosphatides and other impurities) middle layer and an oil top layer (figure 1d). The bottom and middle layers were ran off while the oil layer was collected into a clean beaker for further processing.



Fig 1(a) Water heated to 70°C



Fig 1 (b) Groundnut oil heated to 70°C



Fig 1 (c) Degumming Process of the Extracted Groundnut Oil Plate



Fig 1 (d) The separation of the Gum from Groundnut Oil

- *Alkali Refining of Oil:*

Alkali refining was carried out by measuring 195ml of oil into a beaker and heating the oil to 80°C, 975ml of 0.8m KOH/g standard solution was gradually added while stirring on the constant temperature magnetic stirrer. The mixture was stirred for 15minutes (figure 2a). The mixture was then poured into a separating flask and allowed to stand overnight (20 hours). The mixture separated into three layers; an aqueous bottom layer, a soap middle layer and an oil top layer (figure 2b). The two bottom layers were run off, while the oil top layer was collected for further processing.



Fig 2 (a) Alkali Refining of the Feedstock



Fig 2 (b) Allowing the Refined Groundnut Oil to Separate

- *Purification of Alkali Refined Oil:*

The oil obtained from alkali refining was measured (80ml) and a little quantity of petroleum ether was added so that the soap in the oil can be separated (figure 3a). The oil was then filtered out using filter paper to remove soap and other impurities (figure 3 b). The oil was then mixed with 100ml of distilled water and heated to a temperature of 70°C until the aqueous layer became clear and neutral to litmus paper. A small amount (pinch) of  $\text{Na}_2\text{SO}_4$  (Sodium Sulphate) was added to dry the remaining water added to the oil.



Fig 3 (a) The Purified Groundnut Oil



Fig 3 (b) Filtering the Purified Groundnut Oil

- *Transesterification of Refined Oil:*

0.35g of KOH was weighed and dissolved in 100ml of methanol in a beaker; the methanol was stirred till the KOH pellets dissolved fully. 50ml of oil was heated to 60°C and 100ml methanol was added gradually while stirring the mixture. The reaction time of the transesterification was 70 minutes. After which the mixture was poured into a separating flask and allowed to stay overnight (about 20 hours) (figure 4a). The glycerol bottom layer was run off while the biodiesel top layer was collected. The biodiesel was then heated to 60°C to get rid of the excess methanol. The pure biodiesel was then collected into a clean beaker (figure 4b). The biodiesel had the characteristics smell of groundnut oil.



Fig 4 (a) Biodiesel Left to Separate



Fig 4 (b) Pure Biodiesel after Removing Excess Methanol

➤ *Blending of Biodiesel with Petrodiesel:*

The blends were prepared in proportion to give B10, B20 and B30 blends of biodiesel. The quantity of blends required for analysis was 50ml for each. For the B10 blend, 5ml of groundnut oil was blended with 45ml of petrodiesel to produce blend B10. For blend B20, 10ml of groundnut oil was blended with 40ml of petrodiesel to produce blend B20. For blend B30, 15ml of groundnut oil was blended with 35ml of petrodiesel to produce blend B30 (figure 5a and b). figure 5c shows the biodiesel/petrodiesel blend ratio.



Fig 5 (a) The Blended Biodiesel with Petro Diesel to be Analysed



Fig 5 (b) The Biodiesel and its Blend Package for Analysis

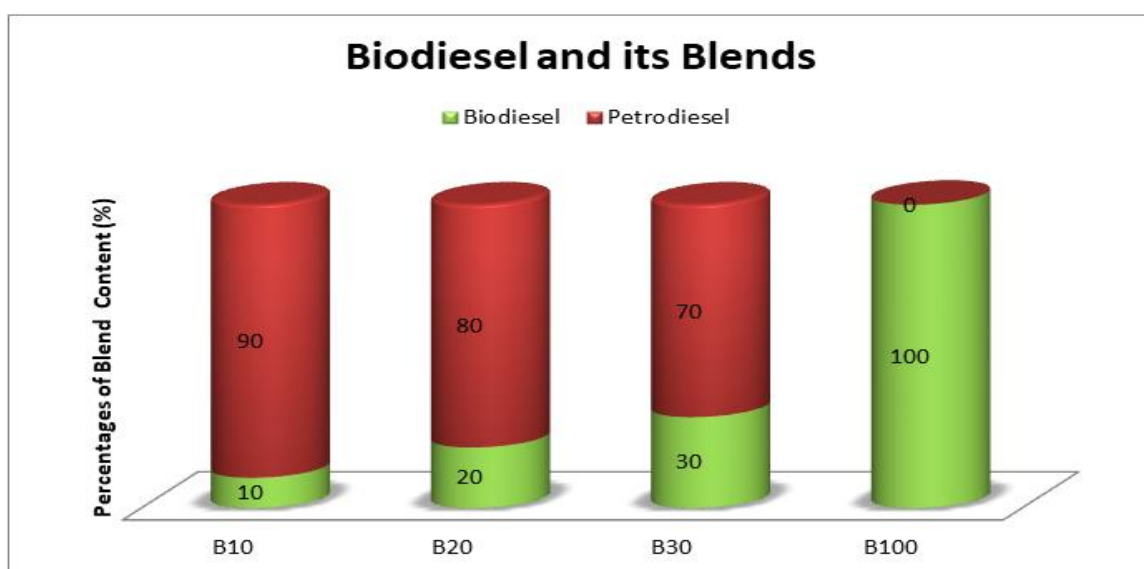
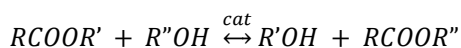


Fig 5 (c) Chart showing Biodiesel Blend Ratio

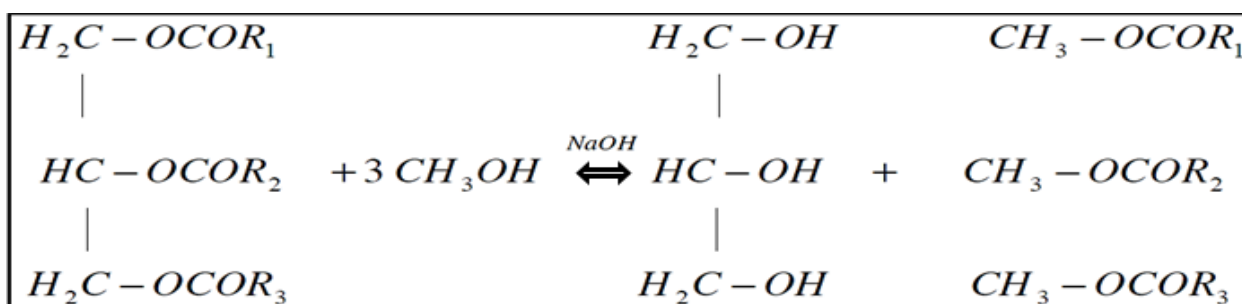
➤ Analysis of the Biodiesel and its Blends:

• Equation of the Biodiesel and its Blends:

A generic transesterification reaction is presented below; RCOOR' indicates an ester, R''OH indicates an alcohol, R'OH indicates another alcohol (glycerol), RCOOR'' indicates an ester mixture and cat (a catalyst):



When methanol is the alcohol used in the transesterification process, the product of the reaction is a mixture of methyl esters.



• *Specific Gravity:*

Specific gravity was determined according to ASTM D-287. A 50ml specific gravity bottle was washed cleaned and dried. It was filled with water maintained at 15°C and weighed again. The bottle was emptied, dried and filled with oil and weighed. The value was calculated using the equation below.

$$\text{Specific gravity} = \frac{\text{weight of oil (Sample)}}{\text{weight of water @ 15}^\circ\text{C}}$$

Table 5 Calculation of Specific Gravity of Biodiesel and its Blends

<b>Specific Gravity</b>	<b>B10</b>	<b>B20</b>	<b>B30</b>	<b>B100</b>
Weight of Empty (g) [grams]	5.45	5.436	5.46	5.546
Weight of Empty + Sample [grams]	11.68	11.673	11.423	12.05
Weight of Sample (m) [grams]	6.23	6.237	5.963	6.504
Volume of Sample (v)	7.5	7.4	7	7.5
<b>Specific Gravity=(m/v)</b>	<b>0.8307</b>	<b>0.8428</b>	<b>0.8519</b>	<b>0.8672</b>

Table 6 Calculation of Density from Specific Gravity

<b>Density</b>	<b>B10</b>	<b>B20</b>	<b>B30</b>	<b>B100</b>
Specific gravity of Sample (s)	0.8307	0.8428	0.8519	0.8672
Density of water (w) [kg/m <sup>3</sup> ]	1000	1000	1000	1000
<b>Density = (s *w) [kg/m<sup>3</sup>]</b>	<b>830.7</b>	<b>842.8</b>	<b>851.9</b>	<b>867.2</b>

• *Flash Point:*

The flash point was tested using the semi-automatic Cleveland flashpoint tester. The minimum temperature was 15°C. The intervals were 2seconds. The starting temperature was 25°C while the ambient temperature was 26°C.

• *Cold Flow Properties:*

In measuring the Pour point, a 15 ml sample initially at 45°C was cooled at specified rate and examined at interval of 3°C to check if the sample is still flowing. The cloud point was determined by a cloud point meter which comprises of a waveguide sensor of a total-reflection type, the wave guide sensor including a wave guide having an incidence channel, an emergency channel and a detection surface all formed on a substrate, the incidence and emergency channels intersecting along the detection surface, an incidence optical fibre connected to the entrance of the incidence channel, and an emergency optical fibre connected to the exit of the emergence channel; and a cooling/heating means in contact with the waveguide sensor for cooling/heating the waveguide sensor within a desired temperature range.

• *Refractive Index:*

Abbe refractometer with a light compensation was used to measure the refractive index. The refractive index was read off on the refractometer after placing the sample in the sample chamber.

• *Calorific Value:*

The calorific was carried out using an Oxygen bomb calorimeter. The weight of the sample plus 10cm ignition wire was measured. The two ends of the wire were fixed to

two electrode poles and allowed to have good contact with the sample that was tested. The Oxygen bomb was then filled with water and screwed tight. The bomb was subsequently filled with Oxygen at a pressure of 2.8 to 3.0 MPa. The Oxygen bomb was then placed in the inner canister and the necessary wires connected. The temperature sensor was also placed in the inner canister.

The power and stir buttons were switched on. The water was allowed to stir constantly for about 2 minutes. The initial temperature of the water was recorded. The fire button was pressed. The instrument automatically measured and saved the data when the testing time got to 31. The final temperature of the water was recorded. The stirring was stopped, the temperature sensor pulled out and the lead opened. The unburned length of the wire was measured. The inner lining of the Oxygen bomb was washed by some distilled water. Two drops of methyl red indicator was added and titrated with 0.0709N Sodium Carbonate. The consumed volume of alkali used was then recorded. The heat of combustion was calculated using the equation

$$W = \frac{E\Delta T - \phi - V}{M}$$

Where,

- W = Calorific value of sample
- E = Energy equivalent of the calorimeter
- Φ = Correction for heat of combustion of firing wire
- ΔT = Change in temperature
- V = Millimetres of standard alkali solution used
- M = Mass of sample evaluated



Table 7 Calculation of Calorific Values of Biodiesel and its Blends

<b>Calorific Value</b>	<b>B10</b>	<b>B20</b>	<b>B30</b>	<b>B100</b>
Weight of Sample (g) [grams]	1.004	1.001	1.003	1.002
Initial Temperature T <sub>1</sub> [°C]	26.892	26.958	27.044	27.12
Final Temperature T <sub>2</sub> [°C]	29.924	29.826	29.713	29.488
Change in Temperature ΔT = T <sub>2</sub> - T <sub>1</sub> [°C]	3.032	2.868	2.669	2.368
Unburnt Wire [mm]	3.4	4.1	4.3	4.8
Burnt Wire (b) [mm]	6.6	5.9	5.7	5.2
Correction of Heat of Combustion (φ) = 2.3 * b	15.18	13.57	13.11	11.96
Millimeters of standard alkali solution (V)	6.8	6.4	6	5.1
Energy Equivalent of Calorimeter €	13039.3	13039.3	13039.3	13039.3
<b>Calorific Value = [EΔT - φ - V]/g</b>	<b>39355.8</b>	<b>37339.4</b>	<b>34678.8</b>	<b>30798.4</b>

- Saponification Value:*

Two grams of the oil was put in a 250ml conical flask. 25ml of alcoholic potassium hydroxide solution was added. A reflux condenser was then attached and the flask was heated for 1 hour. 1ml of 1% phenolphthalein solution was added and titrated with 0.5M HCl (titration = a ml). A blank was also carried out (titration = b ml)

$$\text{Saponification} = \frac{(b - a) \text{ml} \times 28.05}{\text{weight of sample (g)}}$$

Table 8 Calculation of Saponification Value

<b>Saponification Value</b>	<b>B10</b>	<b>B20</b>	<b>B30</b>	<b>B100</b>
Weight of Sample (g) [grams]	2	2	2.003	2.001
Blank titre (b)	21.6	21.6	21.6	21.6
Sample titre (a)	15.1	13.8	12.5	11.4
<b>Saponification Value = [(b - a)*28.05]/g</b>	<b>91.16</b>	<b>109.4</b>	<b>127.44</b>	<b>142.98</b>

- Acid Value:*

This was carried out by mixing 25ml of diethyl ether and 25ml of ethanol. 1ml of phenolphthalein indicator was added. It was neutralized using 0.1M Potassium Hydroxide (KOH). 3 gram of the oil was the dissolved by heating in the solvent mixture. It was then titrated with 0.1M potassium hydroxide solution while shaking constantly till a pink colour which persisted for 15 seconds was observed.

$$\text{Acid value} = \frac{\text{Titration vol(ml)} \times \text{Molarity of KOH} \times 5.61}{\text{Weight of sample used} \times 10}$$

Table 9 Acid Value Calculation

<b>Acid Value</b>	<b>B10</b>	<b>B20</b>	<b>B30</b>	<b>B100</b>
Weight of Sample (g) [grams]	5.004	5	5.004	5.002
Titre Value (T)	0	0	0.1	0.8
Molarity of KOH (M)	0.1	0.1	0.1	0.1
<b>Acid Value = [(T*M*56.1)/(10*g)]</b>	<b>0</b>	<b>0</b>	<b>0.01</b>	<b>0.09</b>

Table 10 Viscosity Calculation from Analysis

<b>Viscosity</b>	<b>B10</b>	<b>B20</b>	<b>B30</b>	<b>B100</b>
Time of flow of sample ( $t_1$ ) [s]	82	84	86	120
Time of flow ( $t_2$ ) [s]	50.3	50.3	50.3	50.3
Diameter of pipe ( $d_1$ ) [mm]	1.005	1.005	1.005	1.005
Diameter of flow ( $d_2$ ) [mm]	1	1	1	1
Density of Sample ( $\rho$ ) [kg/cm <sup>3</sup> ]	0.8309	0.843	0.8521	0.8674
<b>Viscosity = <math>(\rho * d_1 * t_1) / (d_2 * t_2)</math></b>	<b>1.36</b>	<b>1.42</b>	<b>1.46</b>	<b>2.08</b>

Table 11 Volatile Matter Calculation

<b>Volatile Matter</b>	<b>B10</b>	<b>B20</b>	<b>B30</b>	<b>B100</b>
Weight of crucible [grams]	14.63	13.79	12.59	10.45
Weight of crucible + sample [grams]	16.3	17.37	16.04	12.444
Weight of Sample (g) [grams]	1.671	3.578	3.447	1.994
Weight of crucible + dry matter [grams]	15.54	16.11	14.93	12.36
Weight of dry matter (x) [grams]	0.914	2.32	2.345	1.91
Weight of crucible + residue [grams]	14.63	13.79	12.59	10.453
Weight of residue (y) [grams]	0.001	0.001	0.001	0.003
<b>Volatile matter = <math>[(x-y)/y]*100</math></b>	<b>54.64</b>	<b>64.81</b>	<b>68</b>	<b>95.64</b>

Table 12 Calculation of Ash Content

<b>Ash Content</b>	<b>B10</b>	<b>B20</b>	<b>B30</b>	<b>B100</b>
Weight of Crucible [grams]	28.562	14.126	20.18	24.918
Weight of Crucible + Sample [grams]	29.569	15.138	21.185	25.92
Weight of Sample (g) [grams]	1.007	1.012	1.005	1.002
Weight of Crucible + Ash [grams]	28.563	14.127	20.181	24.919
Weight of Ash (x) [grams]	0.001	0.001	0.001	0.001
<b>Ash Content = <math>[(x/g)*100]</math></b>	<b>0.1</b>	<b>0.1</b>	<b>0.1</b>	<b>0.1</b>

Table 13 Moisture Content Calculation

<b>Moisture Content</b>	<b>B10</b>	<b>B20</b>	<b>B30</b>	<b>B100</b>
Weight of Sample (g) [grams]	0.5	0.5	0.5	0.5
Weight of dry matter (x) [grams]	0.4998	0.4999	0.4999	0.5
Loss in Weight (g-x) [grams]	0.0002	0.0002	0.0001	5E-05
<b>Moisture Content = <math>((g-x/g) * 100)</math></b>	<b>0.04</b>	<b>0.03</b>	<b>0.02</b>	<b>0.01</b>

#### IV. RESULT PRESENTATION, ANALYSIS AND DISCUSSION

##### ➤ Results:

This chapter encompasses the results and observation through all of the processes preceding transesterification and blending. This chapter also contains the result of the analysis and cost of the biodiesel and its blends. In this chapter, the result of the analysis is also discussed in detail.

##### ➤ Result Presentation:

The first phase was the degumming of the groundnut oil to remove some impurities from the oil. The degumming phase proceeded well separating into three layers, the oil upper layer, the gum middle layer and the water bottom layer. The water and gum layers were ran off while the oil was used for alkali refining. The result of the alkali refining was not very desirable; too much soap was formed while very little oil was collected. The treatment oil the refined oil with petroleum ether and the subsequent washing with water proceeded well yielding much oil. The transesterification phase went well, separating into a biodiesel top layer and a glycerine bottom layer. The yield of the transesterification was above ninety percent. The biodiesel blended seamlessly with the petrodiesel to form homogeneous blends that were clear in appearance.

Table 14 Table of Characteristics of Biodiesel and its Blends

Properties	Units	B10	B20	B30	B100
Density	Kg/m <sup>3</sup>	830.7	842.8	851.9	867.2
Viscosity	mm <sup>2</sup> /s	1.36	1.42	1.46	2.08
Calorific Value	kJ/kg	39,355.78	37,339.43	34,678.77	30,798.43
Flash Point	°C	60	94	100	160
Cloud Point	°C	-6	0	2	4
Pour Point	°C	-10	-2	0	2
Acid Value	mgKOH/g	0.0	0.0	0.01	0.09
Volatile Matter	%	54.64	64.81	68.00	95.64
Moisture Content	%	0.04	0.03	0.02	0.01
Ash Content	%	0.01	0.01	0.01	0.01
Refractive Index		1.4696	1.4680	1.4653	1.4525
Conductivity	γ <sup>s</sup> /cm	Nil	Nil	Nil	Nil
Saponification Value	mgKOH/g	91.16	109.40	127.44	142.98
Specific Gravity	Kg/m <sup>3</sup>	0.8307	0.8428	0.8519	0.8672

##### ➤ Cost Analysis for Producing Biodiesel B100, B30, B20 and B10

Producing a litre of Biodiesel B100 from groundnut oil using non-analytical grade of methanol and KOH.

Table 15 Cost estimate of Producing Biodiesel in Commercial Quantity

S/N	Material	Quantity	Cost (₦)
1.	Groundnut Oil	1.2 Litres	840
2.	Methanol	0.24 Litres	200
3.	KOH	7 grams	50
4.	Power	3.81Kwh	100
5.	Wash water	6 Litres	10
<b>Total</b>			<b>1200</b>

Therefore, the total cost of producing one litre of B100 is One Thousand Two Hundred Naira (₦1, 200.00) only and a drum of two hundred and ten litres (210 litres) will be Two Hundred and Fifty-Two Thousand Naira (₦252, 000.00) only.

The Cost of producing different blends of Biodiesel can therefore be calculated as follows:

Taking the current pump price of diesel to be Two Hundred and eighty Naira (₦280.00) only and a drum of diesel to be two hundred and ten (210) litres.

Table 16 Cost of Blend B30

S/N	Materials	Quantity	Cost (₦)
1.	Petro diesel	0.7 Litres	196
2.	Biodiesel	0.3 Litres	360
<b>Total Cost of 1 Litre of B30</b>			<b>556</b>
<b>Total Cost of a drum of B30</b>			<b>116760</b>

Table 17 Cost of Blend B20

S/N	Materials	Quantity	Cost (₦)
1.	Petro-diesel	0.8 Litres	224
2.	Biodiesel	0.2 Litres	240
<b>Total Cost of 1 Litre of B20</b>			<b>464</b>
<b>Total Cost of a drum of B20</b>			<b>97440</b>

Table 18 Cost of Blend B10

S/N	Materials	Quantity	Cost (₦)
1.	Petro-diesel	0.9 Litres	252
2.	Biodiesel	0.1 Litres	120
<b>Total Cost of 1 Litre of B10</b>			<b>372</b>
<b>Total Cost of a drum of B10</b>			<b>78120</b>

The cost of producing one litre of biodiesel blends B30, B20 and B10 are five hundred and fifty-six naira (₦556.00); four hundred and sixty-four naira (₦464.00) and three hundred and seventy-two (₦ 372.00) Naira only respectively while the cost of B100 and petro-diesel stands at One thousand two hundred (₦ 1,200.00) and two hundred and eighty (₦ 280.00) naira respectively.

➤ *Discussion of Result*

The results show that groundnut oil or peanut oil is a good feedstock for biodiesel production. From the result of the analysis carried out on the biodiesel and its blends. It was observed that the pure biodiesel (B100) has qualities that meet the ASTM D6751 standard for some of the properties tested. The kinematic viscosity at 40°C was 2.08mm<sup>2</sup>/s which falls between the 1.9 – 6.0mm<sup>2</sup>/s which makes it suitable for use in diesel engines. The viscosity also falls between the requirement established by diesel engine manufacturer DEUTZ of Germany, for countries where there is neither European biodiesel according to the standard EN14214 nor United States biodiesel according to standard ASTM D6751 for pure biodiesel or ASTM D7467-10 (for blends of ratio 6 – 20% biodiesel by volume). Though, the blends B10, B20, B30 all fell short of the standard required producing, 1.36mm<sup>2</sup>/s, 1.42mm<sup>2</sup>/s and 1.46mm<sup>2</sup>/s respectively. These blends did not meet the 1.9 - 4.1 mm<sup>2</sup>/s for ASTM D7467-10 or the 1.8 – 5.0mm<sup>2</sup>/s required by DEUTZ. This shortfall can be as a result of the petrodiesel used for the blending. It can be seen that the kinematic viscosity improved as the quantity of petrodiesel reduces.

The acid number of the pure biodiesel B100 was 0.09 while those for the blends B10, B20 and B30 were 0.0, 0.0 and 0.01 respectively. These values fell below 0.5mgKOH/g maximum standard stipulated by the ASTM for B100 and blends between B6 – B20. This results show that the acid number was improved with blending.

The specific gravity for the pure biodiesel B100 was less than the 0.95 maximum limits for diesel engines. The density of the biodiesels B10, B20, B30 and B100 were 822, 830.9, 852.1 and 867.4 kg/m<sup>3</sup> respectively. Though the ASTM do not have standard for density, the European standard EN14214 for biodiesel, gives a range of 800 to 900 kg/m<sup>3</sup>. Diesel engines manufactures (DEUTZ of Germany) gives a range of between 820 to 876 kg/m<sup>3</sup> for biodiesels in countries in which there is no US Biodiesel or Blends between B6 – B20 for which the US have standards. So the biodiesels B10, B20, B30 and B100 all meet the standard available for use.

The flash points of the biodiesel were reported to be 60°C, 94°C, 100°C and 160°C for B10, B20, B30 and B100 respectively (figure 6 below). This value meets the ASTM standard (ASTM D6751-11a for B100) which recommends a minimum of 93°C and the 130°C in the previous standard (ASTM D6751). The values for the blends are also higher than the 52°C minimum for Blends between B6 – B20 in ASTM standard 07467-10 for biodiesel blends.

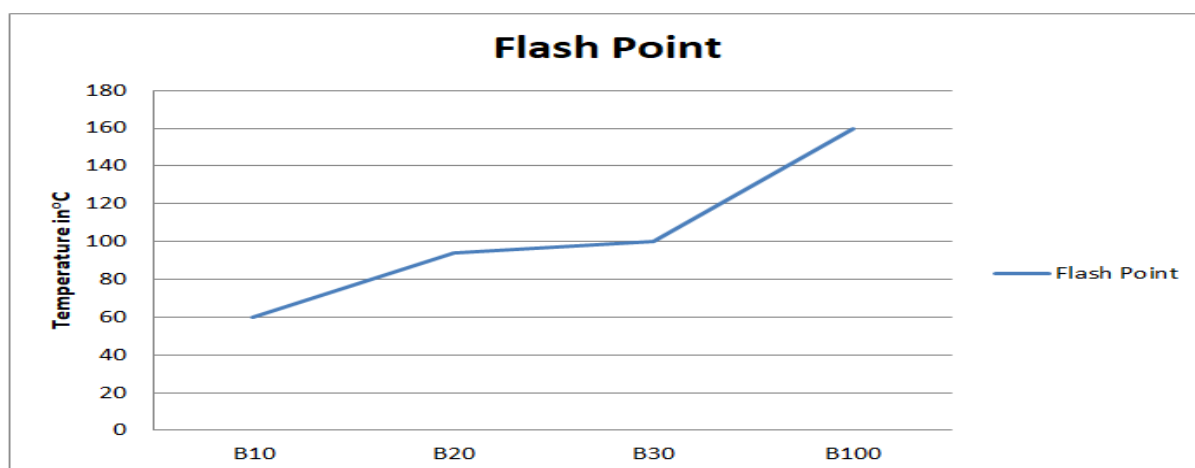


Fig 6 A graphical Representation of the Flash Points of the Various Biodiesel Blends

ASTM does not have a limit for biodiesel as well as their blend, when it comes to cloud point and pour point. They only advocate that such values are reported by the supplies. (DEUTZ of Germany), however, gives a clue for checking for the usability of biodiesel based on cloud point. The parameter for use in checking was ambient temperature of the area of use. The cloud point has to be less than the ambient temperature. The cloud point check for our biodiesel and the blends were reported to be -6°C, 0°C, 2°C and 4°C for B10, B20, B30 and B100 respectively (figure 4.2). In Nigeria, however, ambient temperatures are higher than 10°C in all parts of the country at all times. That implies that the biodiesel and its blends will be good enough for use in this country based on the cloud point.

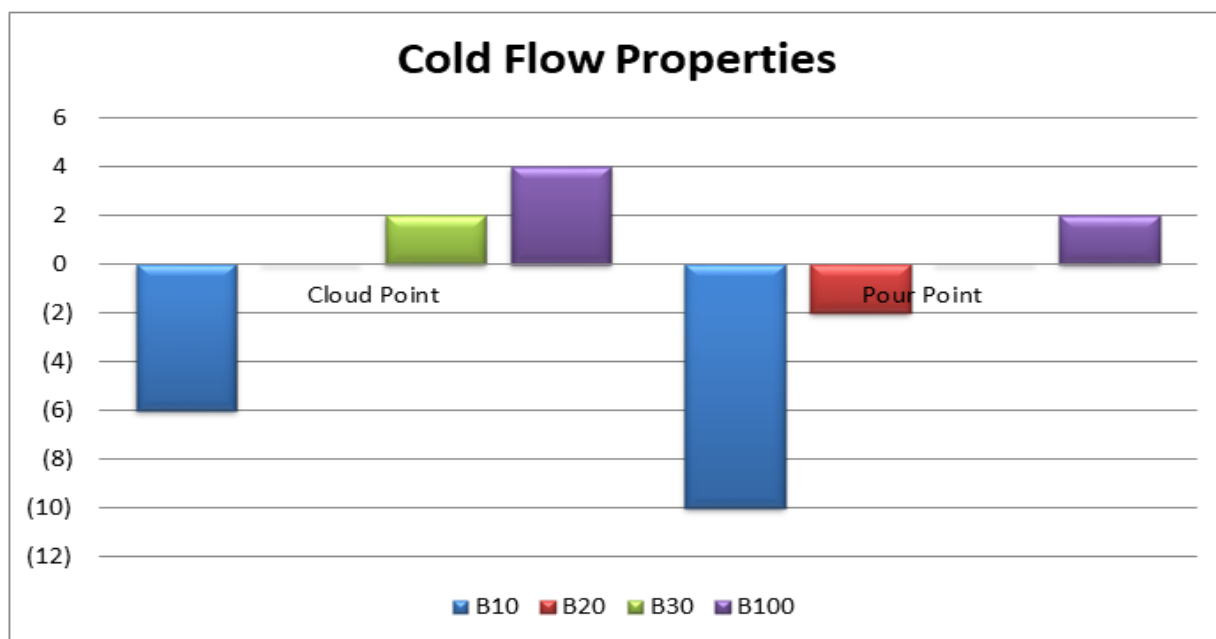


Fig 7 Chart showing the Cold Flow Properties

DEUTZ recommends that pour point should be at least 6°C lower than the ambient temperature. The pour points reported for our biodiesels were -10°C, -2°C, 0°C and 2°C. These figures are more than 6°C less than the ambient temperature in Nigeria at any time of the year. This means that our biodiesel again passes the test.

The calorific value for the biodiesels are 39, 355.78, 37, 339.43, 34, 678.77 and 30, 798.43 J/g for B10, B20, B30 and B100 respectively. The biodiesels B10, B20, B30 and B100 all have no conductivity, saponification value for the blends are 91.16, 109.40 and 127.44 for B10, B20 and B30 respectively. There is no limit for saponification values. High saponification value, however, indicates the presence of high percentage of fatty acids which might lead to soap formation, hence the separation of products was exceedingly difficult especially during the alkali refining.

The moisture content of the biodiesels was initially too high. They ranged from 18%, 16%, 14% and 1.96% for B10, B20, B30 and B100. This showed that there was need to get rid of the excess moisture. This was done by the addition of 0.04, 0.03, 0.02 and 0.01 for B10, B20, B30 and B100 respectively. This was below the ASTM D6751 and D7467 standard that pegs the moisture content at 0.05 maximum. The fact that the moisture content is lower for B100 and higher for B10 indicates that the petrol-diesel used might have had higher moisture than that of the biodiesel B100.

The biodiesel contains more volatile matter than the blends. The pure biodiesel B100 has 95.64 while the blends have 54.64, 66.81 and 68.00 for B10, B20 and B30 respectively. The blending did not affect the ash content of the biodiesel. The biodiesel B100 and the blends B10, B20 and B30 all have the same value of ash content which is 0.01. The refractive index of biodiesels and blends were 1.4696, 1.4680, 1.4653 and 1.4525 for B10, B20, B30 and B100 respectively.

Tables 15-18 above shows that the cost of producing biodiesel and its blends far outweighs the cost of petrodiesel. While this is true, the benefits of biodiesel and its blends also outweighs those of petrodiesel. However, groundnut oil is one of the most expensive edible oils in the market because of its numerous uses. The use of other oils will most likely lower the cost. Also, the use of non-edible oils will very much lower the cost of biodiesel and its blend, making it very affordable. Another viable alternative is the use of used vegetable oil that would ordinarily be poured out as waste. This will ensure a better management of waste oil. More importantly, if more people engage in farming as a way of diversification of our economy the cost of groundnut oil will drastically reduce which will in turn cost a reduction in the cost of producing biodiesel. Nonetheless, since health is wealth, the human and environmental health benefits of biodiesel and its blends makes it the right fuel to use now and in the future.

From the above analysis, it would not be out of place to use blends of up to 30 percent biodiesel in diesel engines in Nigeria. This is because the blend B30 shows improvements on the properties of blends B10 and B20. Since the country does not have biodiesel or their blends currently on sales around the country, it will be suggested that biodiesel blends of between 6 and 30 percent should be advocated for. This will help reduce greenhouse gas emissions and save Nigerians from the health risks that the use of petrodiesel currently poses on Nigerians. Many other researches carried out have shown that B30 has better properties than the current benchmark of B20 currently in use. The regulatory bodies should further investigate these reports by repeating the procedures in the researches to verify the results, after which the benchmark for blending should be updated to take care of higher blends. It is the submission of this work that sometime in the near future, only pure biodiesel (B100) will be used for powering heavy duty engines, as more countries key into the anti-global warming campaign.

## V. SUMMARY, CONCLUSION AND RECOMMENDATIONS

### ➤ Summary:

The importance of transportation to human wellbeing and economic development is an important aspect of lives as it plays a crucial role in agricultural activities, movement of people and in industries. In achieving this, the prime mover makes use of diesel engine using fossil fuels which is categorized by emission of harmful gases into the atmosphere. As such the need to find an alternative fuel such as biodiesel produced from vegetable oil and blend with diesel grades became inevitable. The fuel properties were within ASTM standards. The results of experimental study show that the groundnut oil biodiesel and its blends with diesel can be used successfully in diesel engine without any alteration or modification for such existing engine design.

### ➤ Conclusion:

The purpose of this study was to make comparison between the various properties obtained for the diesel-blend with the ASTM standard and other authors using groundnut oil and diesel grades. This research further affirms the fact that groundnut oil is a very good feedstock for Biodiesel production as shown by the results of the various analyses of the various properties of biodiesel and its blends. The results also shows that the blend ratio can be further increased to 30 percent from the 20 percent it is currently capped at. The results for the blend B30 showed an improvement on B10 and B20 which fall between the currently accepted blend ratios that are widely recommended by diesel engine producer.

### ➤ Recommendations:

Based on the blending of the groundnut oil with diesel grades and the comparison made with the ASTM standards, the following recommendations should be considered:

- The Federal, State and Local government should as a matter of urgency encourage the use of biodiesel and its blends as an alternative fuel for diesel engine in order to discourage act of vandalization, increase engine performance and protect the atmosphere from the hazard caused by emission of gases.
- The government should encourage small scale investment in the area of biodiesel production and blending, these businesses should be given licenses to operate. There should, however, be proper regulation of the subsector so that people do not defraud by supplying pure petrodiesel (B0) as blends or blending with pure oil instead of transesterified oil. The biodiesel industry has the potential of creating jobs for the teeming population, if properly annexed.
- All tertiary institutions should endeavour to boost research work on this new development of using biodiesel and its blends as an alternative fuel for diesel engine by establishing a research centre on alternative energy development.
- With an increased interest in emission and reducing the use of petroleum distillate-based fuels, some government and regulating bodies are encouraging the use of bio fuels. Government incentives and environmental legislation requiring the use of bio fuels may have an impact on the sales and use of engines.
- Adopting biodiesel and its blends as an alternative fuel for diesel engine, produced from Groundnut oils can improve agricultural sector, improve the standard of living of the populace as most people will engage in farming.
- When blending is to be carried out, it is recommended that freshly bought, quality petrodiesel should be used. Petrodiesel must be sourced from petrol stations known for quality product. The petrodiesel should not be stored for long before blending so that the quality does not change.
- Affordable, reliable and easy operate-able machine would be designed and fabricated according to standards to enable individuals (particularly unemployed youths) to set up their own business.

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