Experimental Studies on Neem Seed (*Azadirachta Indica*) as a Possible Engineering Lubricating Fluid

M. N. Idris (Ph.D.) & M. Usman
Department of Chemical Engineering
Faculty of Engineering
University of Maiduguri, Nigeria
Email: idrismn@hotmail.com

I. A. Igbafe
Department of Chemical and Petroleum Engineering
College of Engineering
Afe Babalola University,
Ado Ekiti, Nigeria

Abstract
The gradual depletion of reserves from the petroleum resources and the impact of environmental pollution of increasing exhaust emissions from effluent activities, there is an urgent need to develop alternative energy resources, such as biodiesel fuel and bio-lubricants. This research study is aimed at sorting for alternative lubricant from Neem oil sourced from Neem plant (Azadirachta Indica). The analysis of the physical and chemical properties of Neem oil was carried out and compared with that of a conventional lubricant. Properties such as the free fatty acid, iodine value, viscosity, flash point, fire point, pour point and specific density were determined. The oil yield was 48.6%, iodine value of 56.47g/100g, acid value was 22.1 mg KOH/g, and free fatty acid was 11.11 mg KOH/g. The Neem oil flash and fire point obtained were 265°C and 289°C respectively and they were found to be in line with those obtained in both light duty oil (SAE 30) and heavy duty oil (SAE 40) with flash and fire point values of 243°C/290°C and 260°C/ 300°C, respectively. **.** *From the pour point values obtained, Neem oil which offers a poorer value of 25^{0}C as compared with that of light duty (SAE 30) and heavy duty oil (SAE 40) which has pour point values of 21°C and 9°C. The specific density of 0.910 for the Neem oil conforms to those of Light duty (SAE 30) and Heavy duty (SAE 40) with values of 0.895 and 0.889, respectively. It was also observed that the viscosity of the Neem oil decreased with increase in temperature. This was best with the light duty (SAE 30) which decreased from 104 CST to 12 CST while the Neem oil had viscosity of 109/22.6 cst at 40°C and 100°C. The heavy duty (SAE 40) had a viscosity of 126.4/9.1 CST at 40°C and at 100°C. Therefore Neem oil can successfully serve as a lubricant, based on the lubricant properties it displayed for both light automotive systems and heavy automotive system. But it would be advisable to use Neem oil in hotter regions of the world, and/or to use lubricant additives that would improve the pour point value of the Neem oil.*

Keywords*: Azadirachta Indica, lubricating fluid, depletion, Neem oil properties*

1.0 Introduction

The important need for lubrication cannot be over-emphasized as far as its role in engineering is concerned. With the technological advancement, man in his quest to improve his standard of living continues to invent and produce new machines. When two metal parts are in contact, the amount of asperities and interaction within the contact area increases thereby causing;

frictions which insist motion wear of the metal parts and generation of excessive heat. These friction, wear and excessive heat caused by the interaction between the surfaces of the moving parts of the machine has to be controlled by lubrication whose function is to reduce friction and wear, prevent oxidation and corrosion while acting as a coolant facilitating heat dissipation from the engine. A lubricant may be in gaseous, liquid, semi-solid (grease) or solid form. Lubrication is achieved when the surfaces in contact are separated by a continuous lubricant film. The lubricant is expected to have lower shear strength than that of the materials of the contact surfaces and also be able to withstand the loading of the parts in contact. The improved quality of today's synthetic lubricants has enabled the design of machines with higher stresses, load and operating temperature than before. Consequently, automobile engines capable of high rotational speed and higher specific power have been produced. Liquid lubricants have the highest application because they headily provide the separation of surfaces when correctly applied. They also perform other functions of a lubricant as discussed earlier Hassan and Abolarin (2008).

Neem (*Azadirachta Indica*) tree is a native to tropical South East Asia and some part of Africa, belong to Mahogany family or known as *Meliaceae*. This tree is popularly known as dogonyaro in Nigeria. All parts of this tree are very useful in variety of biological activity. The most famous part of this tree is the oil obtained from the kernel of its seed (Tunmise et al., 2002).

Neem oil is expressed from the seed of the *Azadirachta Indica* have found its use widely in different region of the globe for medicinal and agricultural purpose (Tunmise et al., 2002).
It is used in soap production, as raw material for producing commercial pesticides and cosmetics, plant protection, stock and textile protection, refining to edible oil, lubrication oil for engines, lamp oil, candle production Francis (2012),. It is found to be of great health use and it has effective anti-germ properties which include the use as an insect repellent and it has shown positive results as pesticide. In India, it has been demonstrated that Neem Oil is a potential new contraceptive for women Tunmise et al., 2002).

2.0 Background Literatures

Studies to propel a lasting solution to the gradual depletion of world petroleum reserves and the impact of increasing exhaust emissions which causes severe environmental pollution remain a crux in this subject. Vegetable oil is a promising alternative because it has several advantages, it is renewable, environmental-friendly and produced easily in rural areas, where there is an acute need for modern forms of energy. Therefore, in recent years several researches having been studied to use vegetable oils as lubricant in engines as biolubrcant (Emil Akbar et al, 2009).

Furthermore, vegetable oil-based products hold great potential for stimulating rural economic development because farmers would benefit from increased demand for vegetable oils. Various vegetable oils, including palm oil, soybean oil, and sunflower oil, rapeseed oil, Neem oil and canola oil have been used to produce biodiesel fuel and bio-lubricants (Gupta and Vivek 2004),.

Bio-lubricant an alternative engine lubricants, is made from renewable biological sources such as vegetable oils and animal fats. It is biodegradable and non-toxic. It also has low emission profiles and so are environmentally beneficial Francis, (2012), Muthu et al., (2010) and Niraj, (2011).

2.1 Advantages of Bio-Lubricant

Availability and renewability of bio-lubricant - Bio-lubricant is the only alternative fluid with the property that low concentration; bio-lubricant will run well in unmodified conventional engines. Bio-lubricant can be made from domestically produced, renewable oilseed crops such as soybean, rapeseed and sunflower Neem oil. The risks of handling, transporting and storing biodiesel are much lower than those associated with petroleum diesel. Bio-lubricant is safe to handle and transport because it is as biodegradable as sugar and has a high flash point compared to petroleum diesel fuel. Bio-lubricant lower emission from engine - Bio-lubricant provides significant reductions in particulates and carbon monoxide over lubrication in engine. Bio-lubricant provides a slight increase or decrease in nitrogen oxides depending on engine family and testing procedures. Because bio-lubricant is made from renewable sources, it presents a convenient way to provide lubricant to engine while protecting the environment from unwanted emissions. Biodegradability of bio-lubricant - Biodegradable lubricant has an expanding range of potential applications and environmentally friendly. Therefore, there is growing interest in degradable lubricant that degrades more rapidly than conventional lubricant. Its oxygen content improves the biodegradation process, leading to an increased level of quick biodegradation Niraj, (2011).

2.2 Description and Characteristics of Vegetable-based Lubricant Fluid

Vegetable seed oils belong to a chemical family called 'natural esters'. These are simply oils that are extracted from vegetable seeds. Nearly all types of seeds contain oil, however only some type are present in sufficient quantities or possess characteristics needed to be commercially viable lubricant oils.

Chemically, natural esters are called 'triglycerides'. These are made up of a glycerol molecule plus three molecules of "fatty acids". There are many naturally occurring fatty acids, which are simply chains of hydrogen and carbon atoms, attached by either single chemical bonds or double chemical bonds. Most naturally occurring fatty acids have chains with four to 28 carbon atoms Muthu et al., (2010).

The types of fatty acids in the natural ester molecule will determine the ester's physical and chemical characteristics, such as viscosity, pour point, and especially, its resistance to oxidation. If the fatty acid portion of the molecule has many double bonds between the different carbon atoms, then the resulting natural ester will have poor oxidation stability, as the oxidation reaction occurs at the double bond John, (2008), David, (2012) and (Maria et al., 2008).

3.0 Materials and Methods

3.1 Instrumentation Used

Table 1 List of instruments and equipments used

S/N	EQUIPMENT	MANUFACTURER	USES
1	Heating Mantle	Electrothermal™ England, London	For heating during solvent extraction process
2	Round Bottom Flask	Quickfit™ England, London.	For containing extraction sample during extraction process
3	Mortar and crusher		For de-shelling and crushing the dry Neem seed to finer particles.
4	Soxhlet Apparatus	Quickfit™ England, London.	For Neem seed oil extraction using the solvent extraction method.
5	Condenser	Quickfit™ England, London.	For Neem seed oil extraction using the solvent extraction method.

6	Measuring Cylinder	Witeg^{TM} W. Germany.	For liquid volume measurements.
7	Retort Stand		For granting structural support to glassware apparatus set-up.
8	Beaker	Schott Duran^{TM} W.Germany.	For containing liquid samples during the experiment.
9	Mattler electronic balance	Mettler^{TM}	For weighing of samples.
10	Thermometer	Quickfit^{TM} Great Britain.	For temperature measurement during pour point determination.
11	Viscometer	Brookfield Engineering Laboratories. 11 Commerce Blvd. Middleboro, USA.	For the determination of lubricant's viscosity.
12	Cleveland close cup Apparatus	Pensky Martens	For flash/ fire point determination.

3.2 Experimental Methodology

Materials used for the experiments were:

1. Ripe-dried Neem seed sample were collected at University of Maiduguri Teaching Hospital Quarters.
2. N-hexane as the solvent for the extraction of the Neem seed (5 litres).
3. Phenolphthain as indicator (few drops).
4. 0.1N KOH solution (about 200 ml).
5. Diethyl ether and ethanol mixture (about 200 ml)

3.3 Experimental Procedure

Step 1: Seed Preparation and Oil Extraction with the use of Soxhlet extractor.
Step 2: Chemical and Physical analysis of Neem oil. The oil content, analytical test on Neem oil were carried out.
Step 3: Experimental testing. The determination of Iodine value (I.V.), acid value and free fatty acid determination, flash point and fire point, pour point, density and viscosity test was carried out.

Some experimental pictures were represented as shown below:

Fig 1 Digital weighing of Neem seed

Fig 2 Mortar and crushed Neem seed

Fig 3 Extracted oil from Soxhlet extractor

Fig 4 Viscometer measurement

4.0 Results

The results of the research work findings were presented in this chapter.

Table 2: Tabular results for standard test on the physiochemical analysis of Neem oil

S/No.	Property	Value	Unit
1.	*Colour*	*Brown*	-
2.	*Odour*	*Garlic*	-
3.	*Oil contents*	*48.6*	*wt.%*
4.	*Iodine value*	*56.47g/100g*	*g/g*
5.	*Acid value*	*22.1*	*mgKOH/g*
6.	*FFA*	*11.11*	*mgKOH/g*
7.	*Viscosity at 40^{o}C*	*109*	*[cst]*
8.	*Viscosity at 100^{o}C*	*22.6*	*[cst]*
9.	*Pour point*	*25*	*^{0}C*
10.	*Fire point*	*289*	*^{0}C*
11.	*Flash point*	*265*	*^{0}C*
12.	*Refractive index*	*1.42*	-

Table 2 presented above depicts the results of the Neem oil extracted and processed. This table outlined the physicochemical analysis of the oil from Azadirachta Indica. Table 3 represents the standard comparison of the experimented and produced Neem oil with a conventional lubricant using the standard of Society of Automobile Engineers (SAE30).

Table 3: Tabular comparison between the experimental Neem oil and conventional lubricants obtained from Society of Automobile Engineers (SAE30).

S/No.	Property	Experimental Neem oil	Unipetrol SAE30	Deviation (%)
1.	Flash Point [^{o}C]	265	243	9
2.	Fire Point [^{o}C]	289	290	0
3.	Pour Point [^{o}C]	25	21	19
4.	Specific density (kg/m^3)	0.925	0.895	2
5.	Viscosity at 40^{0}C {cst}	109	104	5
6.	Viscosity at 100^{0}C {cst}	22.6	12.1	87

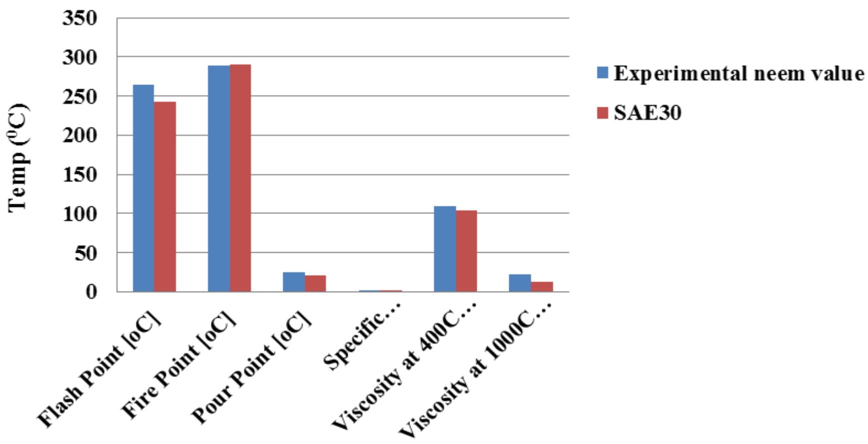

Fig 5: Graphical representation of Experimental Neem oil value and SAE30 showing the deviation in property

Table 4: Tabular comparison between the experimental Neem oil and conventional lubricants obtained from Society of Automobile Engineers (SAE40)

S/No.	Property	Experimental Neem oil	TotalFinaElf SAE40	Deviation (%)
1.	Flash Point [^{o}C]	265	260	2
2.	Fire Point [^{o}C]	289	300	-4
3.	Pour Point [^{o}C]	25	9	178
4.	Specific density (kg/m^{3})	0.91	0.889	2
5.	Viscosity at 40^{0}C {cst}	109	126.4	-14
6.	Viscosity at 100^{0}C {cst}	22.6	9.1	148

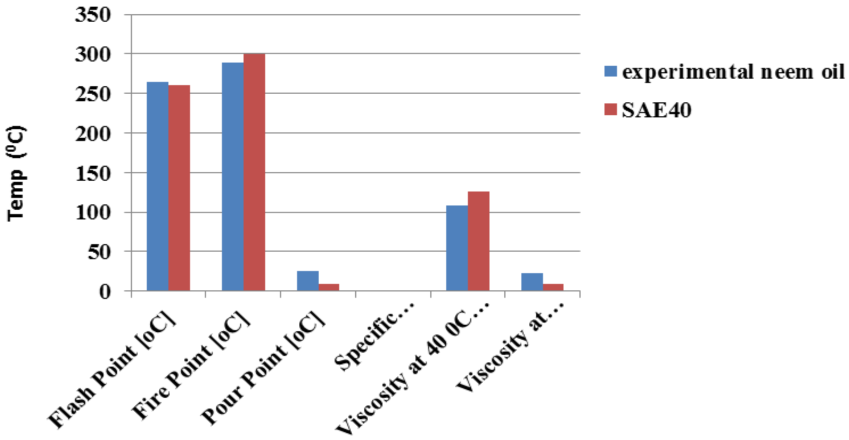

Fig 6: Graphical representation of Experimental Neem oil value and SAE40 showing the deviation in property

5.0 Discussions of Results

The physical and chemical properties of Neem oil obtained from the experiment studies were characterized as depicted in Table 2. Therefore, to have a qualitative value of the Neem oil experimented, it is accurately correct to establish a comparison on the characteristics of the oil and its properties were compared with both that of conventional lubricating fluid. The percentage oil content of Neem seed was found to be 48.6% by weight. The iodine value for extracted Neem oil was obtained to be 56.47g/100g, the low value is not desirable as for higher iodine value of range between 85.8 – 98.4g/100g falls within the class of non – drying oil which means the oil would have low degree of unsaturation. The acid value of Neem oil has high value which is not desirable and it affect the storage duration and the stability of the oil.

The flash point is the minimum temperature at which a lubricant's vapour, when mixed with air, will ignite but will not continue to burn. The fire point is the temperature at which the combustion of a lubricant will be sustained. The flash and fire points are useful in determining a lubricant's volatility and fire resistance. The flash point can also be used to determine the transportation and storage temperature requirements for lubricants. Lubricant producers can also use the flash point to detect potential product contamination. A lubricant exhibiting a flash point significantly lower than normal will be suspected of contamination with a volatile product. Products with a flash point less than 38^0C will usually require special precautions for safe handling. The fire point for a lubricant is usually 8 to 10 percent above the flash point. This was in agreement with the work of Jeffrey, (2009).

Neem oil with a flash and fire point values of 265 and 289 respectively fits in effectively considering its volatility, resistance to temperature for safe transportation and storage, as required by standard lubricant specification producers which can be used for detecting product contamination. When these values were compared with the literature values, it was found out that they were in line with those obtained from both light duty automotive oil (SAE 30) and heavy duty automotive oil (SAE 40) with flash and fire points of 243^0C/290^0C and 260^0C/ 300^0C, respectively**.** The results indicate that the flash and fire points of Neem oil falls within the recommended range Jeffrey, (2009).

The Pour Point is the lowest temperature at which oil will flow. This property is crucial for oils that must flow at low temperatures. A commonly used rule of thumb when selecting oils is to ensure that the Pour Point is at least 10^0C (50^0F) lower than the lowest anticipated ambient temperature Musa, (2009). From the pour point values obtained, Neem oil which offers a poorer value of 25^0C would be less effective to cold regions. Therefore, it would be advisable to use Neem oil in temperate regions of the world, or to use lubricant additives that would improve the pour point value of the Neem oil as compared with that of light duty (SAE 30) and heavy duty oil (SAE 40) which has pour point values of 21^0C and 9^0C.

Density of a substance is defined as its mass per unit volume, the unit being in kilogram per cubic meter. It is always necessary to state the temperature corresponding to a given density, for the latter varies with the temperature, while specific gravity of a substance is generally defined as the ratio of the density of the substance at a given temperature to the density of distilled water at atmospheric pressure. The commonly used standard base temperature widely taken is 4^0C by physicists (Jeffrey, 2009). It was observed that the difference in the density values were small, Neem oil which have higher density of 0.910 as compared with 0.895 and 0.889 for SAE 30 and 40 respectively. This shows that Neem oil can serve as a better option.

The result of viscosity, which shows the response of oil to heat and flame under controlled conditions as presented in the table above shows the viscosity of Neem oil at 40 ^{0}C, 109cts, and at 100 ^{0}C, 22.6cts, as a highly recommended lubricant value. This is because these values satisfy the lubricant requirement specification (from the open literature). And both light and heavy duty systems (SAE 30 & 40) can be substituted, when compared with the lubrication requirements, it is most expected that a lubricant undergoes only a minimal viscosity change with the increasing temperature of the system. This factor would make Neem oil more stable to handle at varying operational temperatures of the system. That means the changes of viscosity is small by the influence of temperature and thus satisfy their use as lubricating oils.

6.0 Conclusions

From the analysis of Neem seed and solvent extraction of its oil using hexane were carried out. Based on the results obtained from the various tests carried out, the following conclusions were drawn:

The flash and fire point values of 265^0C and 289^0C respectively obtained for the Neem oil were found to be in line with those obtained in both light duty oil (SAE 30) and heavy duty oil (SAE 40) which has flash and fire point values of 243^0C/290^0C and 260^0C/ 300^0C respectively**.**

The Neem oil pour point values obtained offers a poorer value of 25^0C as compared with that of light duty (SAE 30) and heavy duty oil (SAE 40) which has pour point values of 21^0C and 9^0C. Therefore Neem oil would be less effective to cold regions.

The specific density of 0.910 for the Neem oil conforms to those of Light duty (SAE 30) and Heavy duty (SAE 40) with values of 0.895 and 0.889 respectively. In this regard, it was obvious that the Neem oil has good density value. Hence, it will settle below in case of contamination with water and will subsequently be drained off.

It was also observed that the viscosity of the Neem oil decreased with increase in temperature. This was best with the light duty (SAE 30) which decreased from 104cst to 12cst, while the Neem oil had viscosity of 109/22.6 cst at 40^0C and 100^0C. The heavy duty (SAE 40) had a viscosity of 126.4/9.1 cst at 40^0C and at 100^0C. On increasing the operating temperatures from 40^0C to 100^0C, the Neem oil samples were analyzed and shown various decreases in their viscosities.

Hence Neem oil can successfully serve as a lubricant, based on the lubricant properties it displayed for both light automotive systems and heavy automotive system. Neem oil can serve as good substitute for both SAE30 and SAE40 due to the higher flash/fire point of the oil for high friction systems like highly automotive systems with heavy duty demands.

Recommendation

The recommendations are as follows:

Since Neem oil offers a pour value of 25^0C, this would be less effective to cold regions. Therefore, it is recommended to use Neem oil in hotter regions of the world, and/or possible applications of additives that would improve the pour point value.

Neem oil would be very effective to use at systems that require a lower viscosity change with the increasing temperature due to its very high viscosity index.

Therefore, the need for more researches to be conducted on the Neem oil properties at different geographical location of the country, in other to verify their temperature differences.

There should be more research on additive that will improve pour point value in other to use Neem oil as a suitable lubricant.

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Corresponding Authors' Biography:

Engr. Dr. Muhammad Nuru Idris has a PhD in Chemical Process Engineering (Modelling and Simulation) from the University of Leeds, United Kingdom. He is currently a ***Reader (Associate Professor)*** with the Department of Chemical Engineering, University of Maiduguri, Nigeria. He is an expert in oil and gas modelling, sustainable energy development. His research interests are on applications of CFD in modelling and simulation of process systems and design, reactions engineering, biotechnology, nanotechnology and sustainable technology.

He has received award which include the PTDF in 2006 and TETFund grant in 2013 for research and development. He is an active and full registered member of the American Institute of Chemical Engineers USA (AIChE senior category), an chartered member of the Institute of Chemical Engineers (IChemE) UK, chartered member of the chemical engineers UK, chartered member of the institution of engineering UK, a member of the Nigerian Society of Engineers (MNSE), awaiting confirmation as a Fellow of the society, member of the Nigerian Society of Chemical Engineers (MNSChE) and registered member of the Council for the Regulations of Engineering in Nigeria (RCOREN) and Professional member of the Materials and Technology Society of Nigeria (MMSN). Engr. Idris is widely travelled worldwide and has many conferences in several countries with many publications in reputable peer reviewed journals. He is a lover of gulf and enjoys swimming. He is ardent to charitable work that helps less privilege. Please contact the corresponding author as stated above of Tel: +234 (0) 705 877 1096