Jurnal Tribologi 23 (2019) 97-112

Jurnal Tribologi
Website : jurnaltribologi.mytribos.org
e-issn: 2289-7232

Nigeria Jatropha oil as suitable basestock for biolubricant production

Timothy Y. Woma [1,*], Sunday A. Lawal [1], Asipita S. Abdulrahman [2], Moses A. Olutoye [3]

[1] Mechanical Engineering Department, Federal University of Technology Minna, Niger State, NIGERIA.
[2] Metallurgical and Materials Engineering Department, Federal University of Technology Minna, Niger State, NIGERIA.
[3] Chemical Engineering Department, Federal University of Technology Minna, Niger State, NIGERIA.
[*]Corresponding author: timothy.woma@gmail.com

KEYWORDS

Jatropha oil
Biolubricant
Viscosity Index
Tribology
Cold flow
Environmentally-friendly

ABSTRACT

Jatropha oil which is a non-edible vegetable oil that is sustainable, biodegradable and environmentally friendly is thought to be a good substitute for mineral oil for lubricant production. The physicochemical, rheological, temperature, thermo-oxidative stability and corrosion properties of Nigerian Jatropha oil and commercially available mineral oil base lubricant (SAE 20W50) were determined for suitability as base stock for lubricant production. The Jatropha oil has specific gravity of 0.91, free fatty acid of 15.6 mg KOH/g , pH of 5.82, saponification value of 220.46 mg KOH/g and Iodine value of 88.9 gI2/100g oil. Assessment of the rheological and temperature properties of the Jatropha oil gave kinematic viscosity at 400C and 1000C as 83.2 cSt and 63.5 cSt respectively, viscosity index of 145.5, pour point of -11.20C, cloud point of -8.30C and flash point of 2640C. The peroxide value of the Jatropha oil was 5.98 meq/Kg and it was of corrosion grade 0. The jatropha oil has better viscosity index compared to the SAE 20W50, whereas the SAE 20W50 is better than the jatropha oil in other measured properties. The properties of the Jatropha oil need to be improved except its cold flow, flash point and corrosion inhibition properties.

Received 8 September 2019; received in revised form 14 November 2019; accepted 2 December 2019.
To cite this article: Woma et al. (2019). Nigeria Jatropha oil as suitable basestock for biolubricant production. Jurnal Tribologi 23, pp.97-112.

1.0 INTRODUCTION

Since the beginning of the industrial revolution, every industry uses machines. These machines have moving contacting parts that generate friction and wear. Friction and wear are the major cause of material and energy loss (Stachowiak and Batchelor, 2000). Lubrication is one of the most effective ways of reducing friction and wear. The science and engineering of moving contacting surfaces is called tribology. Tribology encompases friction, wear and lubrication.

From ancient times vegetable oils have been used as lubricants (Dowson, 1998). Vegetable oil had been the main ingredient of lubricating oils until the 19th century. The requirement of lubricants became very high thereafter because of rapid industrialisation, putting pressure on the price and availability of lubricants from vegetable and animal sources. Mineral oils were started being used as lubricating oils after the successful prospecting and extraction of mineral oils during the second half of the 19th century. Mineral oil became available in large quantities and became cheap replacement for lubricants of vegetable and animal origin (Ajithkumar, 2009). Today mineral oil represents about 95% of the lubricant market worldwide (Jain and Suhane, 2012), and 30% of lubricants consumed ends up in the ecosystem (Bartz, 2006 and Ajithkumar, 2009).

However, mineral oil reserve is depleting, the prices of petroleum products are unstable and the environmental concern about the damaging impact of mineral oil is growing. The search for environmentally friendly substitutes to mineral oils as base oils in lubricants has become a frontier area of research in the lubricant industry (Ajithkumar, 2009; Woma et al., 2019). Vegetable oils are perceived to be alternatives to mineral oils for lubricant base oils due to certain inherent technical properties and their ability to be biodegradable. Chemically, vegetable oils are esters of glycerine and long-chain fatty acids (triglycerides) as shown in figure 1, which have molecular structure with three long chain fatty acids attached at the hydroxyl groups via ester linkages (Lawal et al., 2011).

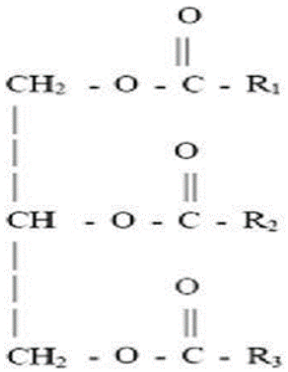

Figure 1: Chemical structure of triglyceride of a typical vegetable oil (Lawal et al; 2011).

Compared to mineral oils, vegetable oils in general possess high flash point, high viscosity index, high lubricity and low evaporative loss (Erhan and Asadauskas, S., 2000; Adhvaryu and Erhan, 2002; Mercurio, et al., 2004). Vegetable oils have been found to be less dangerous to the soil, water, flora and fauna during disposal or accidental spillage compared to mineral oil (Mercurio et al., 2004; Awoyale et al., 2011).

Poor oxidative and hydrolytic stability, high temperature sensitivity of tribological behaviour and poor cold flow properties are reckoned to be the limitations of vegetable oils for their use as base oils for industrial lubricants (Erhan and Asadaukas, 2000; Adhvaryu et al., 2005). The

current effort to overcome these limitations include the use of additives, chemical modifications and thermal modifications (Li and Wang, 2015). A comprehensive review of the challenges and prospects of vegetable oil base lubricants have been carried out by Woma et al., (2019).

Vegetable oil are either edible or non- edible in nature, various countries in the world import edible vegetable oil for food; for example, India has 16.6 million tonnes annual edible oil consumption and is the largest importer of edible oil (Jain and Suhane, 2012). Nigeria is at present a net importer of edible oil, with increasing population and the inability to meet domestic demand for edible oil it is now very challenging to use edible oil for lubricant formulation because of the food versus energy (lubricants and fuel) debate (Woma et al., 2019). Therefore, as alternative non-edible oil is gaining consideration for bio-lubricant and bio-diesel development. Locally available non-edible oil includes Jatropha oil, castor oil, neem seed oil, rice bran oil and karanja oil. This paper presents detail study of Nigerian Jatropha oil properties with particular emphasis on the properties that are of lubrication importance. The detail knowledge of the properties of Jatropha oil will help in identifying the areas that need improvement, so that the oil can be suitable for use as a base stock for lubricant production.

1.1 Review of Recent Research on Nigeria Jatropha Oil Biolubricant

Crude Jatropha oil has been studied as a basestock for industrial lubricant production (Mamuda *et al;* 2016; Silva et al., 2013; Arbian and Salimon, 2010). However, Jatropha oil in its crude form has several limitations and several researches are being carried out to overcome these challenges (Musa et al; 2016; Erhan and Asadauskas, S., 2000; Adhvaryu and Erhan, 2002; Mercurio, et al., 2004). Also it is known that the climatic conditions and the type of soil determine the properties of oils, such that oils from the same species of crop grown in Nigeria will differ in properties from those grown elsewhere in the world (Rani, et al., 2014). Whereas the properties of Asia jatropha oil that are of tribological importance have been studied and documented, very little of the properties of Nigeria jatropha oil is studied. The absence of adequate data on Nigeria jatropha oil properties that are of tribological importance have made this research necessary.

Mamuda et al., (2016) studied the lubricant properties of Nigeria Jatropha oil mechanically extracted in the National Research Institute of Chemical Technology (NARICT), using four ball tester. The properties (friction and wear) of the jatropha oil were compared with that of foreign 10W-30 Arrow premium synthetic oil. The result showed that the unrefined jatropha oil (with friction coefficient of 0.060) had higher friction reduction capability and extreme pressure performance than the 10W-30 synthetic oil (with friction coefficient of 0.076), but performed far less in wear protection. It was concluded that if other properties of the Nigeria jatropha oil are improved, it will meet the requirements as lubricant for elevated temperature wire drawing. The study however did not consider the physiocochemical, temperature, rheological and corrosion protection properties of the Nigeria jatropha oil. The biodegradability of the oil was not tested neither. Knowledge of these properties is necessary if Nigeria jatropha oil properties are to be improved upon for metal working applications.

Bilal et al., (2013) used solvent extraction method to extract jatropha oil from Nigeria jatropha seed. Biolubricant was produced from the Nigeria jatropha oil through a two-step transestrification process using ethylene glycol. The physicochemical, temperature and rheological properties of the produced biolubricant were studied and compared to that of the raw jatropha oil. The results obtained indicated that the biolubricant had a better pour point (-7°C) and lower rheological properties compared to the jatropha oil (with pour point of (5°C). It was concluded that the synthesized biolubricant conformed to the ISO VG46 standard lubricant and

would be a favourable substitute for petroleum-based lubricants for light gear applications. The study did not measure the iodine value, peroxide value, cloud point and flash point of the jatropha oil. The corrosion inhibition properties as well as the biodegradability of the jatropha oil were not determined. These properties are of importance in the application of any oil for lubrication purposes.

Whereas the production of Jatropha oil biolubricant has been optimised (Musa et al, 2016), little success has been achieved in improving the performance of Jatropha based lubricants. To be able to solve some of the challenges that are associated with the use of Jatropha oil as lubricant and to improve the performance of Jatropha based lubricants requires detail knowledge of the properties of the oil. Summary of other researches on Nigeria Jatropha oil as biolubricant and the research gap identified are listed in Table 1. This paper presents detail study of Nigerian Jatropha oil properties with particular emphasis on the properties that are of lubrication importance. The detail knowledge of the properties of Jatropha oil will help in identifying the areas that need improvement, so that the oil can be suitable for use as a base stock for lubricant production.

2.0 MATERIALS AND METHODS

The major materials used in this research were Jatropha oil sourced from Agrienergy Kano, and a mineral oil-based multigrade commercially available lubricant SAE 20/W50 obtained from Amasco Kano, that was used as a control experiment. The Jatropha oil was cold pressed and mechanically extracted from Nigerian grown Jatropha seeds.

2. 1 Determination of Physicochemical Properties of Jatropha Oil

The physicochemical properties (specific gravity, acid value, percentage free fatty acid, iodine value and pH value) of the Jatropha oil were analysed. Details of the analysis are reported in the following subsections.

2.1.1 Determination of Specific Gravity and Density

The density was measured according to the ASTM D1298 standard while the specific gravity was determined according to the ASTM D1217 standard. A 50ml SEDI-M pycometer bottle was washed thoroughly with detergent, water and petroleum ether, it was then oven dried and weighed. The bottle was filled with distilled water and weighed, the bottle was then dried and filled with the oil sample and weighed as shown in Figure 1. From theory, the specific gravity is the mass of the oil weighed divided by the mass of water weighed and the density of the oil was equal to mass of the oil per unit volume.

Table 1: Recent research on Nigeria jatropha oil biolubricants and the identified research gap.

#	RESEARCHERS	TITLE OF WORK	CONTRIBUTION	IDENTIFIED GAP
1	Mamuda, et al; (2016b)	Assessment of Lubricant Properties of J.Curcas Seed Oil and 10W-30 Arrow Premium Synthetic Blend Plus Oil	Jatropha oil performed better than 10W-30 in friction reduction but less in wear protection.	Physicochemical, temperature, rheological, corrosion inhibition properties and biodegradability of the Nigerian jatropha oil were not studied.
2	Bilal et al; (2013)	Production of Biolubricant from Jatropha Curcas Seed Oil	Transesterification of Nigerian Jatropha oil with ethylene glycol improves pour point and gives a lubricant conformable to ISO VG-46	Iodine and peroxide values, cloud and flash points and biodegradability of the Nigerian Jatropha oil were not studied.
3	Garba et al; (2013)	Production and Characterisation of Biobased Transformer Oil from Jatropha Curcas Seed	Degummed jatropha oil meets the ASTM standard for use as transformer oil.	The corrosion inhibition properties and biodegradability of the oil was not studied.
4	Mamuda, et al; (2016a)	Influence of formulated neem seed oil and jatropha curcas seed oil on wire drawing of mild steel and medium carbon steel at elevated temperatures,	Nigeria jatropha oil formulated with Antimony diakyl dithiocarbamate (ADTC) is suitable for wire drawing of mild and medium carbon steel rod	Physicochemical, temperature, rheological, corrosion inhibition properties and biodegradability of the Nigerian jatropha oil were not studied.
5	Musa et al; (2016)	Statistical Optimization of Biolubricant Production from Jatropha Curcas Oil using Trimethylolpropane as a Polyol	Optimised the process conditions for production of biolubricant from Nigeria jatropha oil and Trimethylolpropane.	Focused on the yield of biolubricant from the process without paying attention to the properties of the jatropha oil or the produced biolubricant.
6	Mohammed, N; (2015)	Synthesis of Biolubricant from Vegetable Oils	Transesterification of Nigeria Jatropha, Moringa seed, castor and cotton seed oils with trimethylolpropane improves pour point but degrades rheological properties.	Iodine and peroxide values, cloud and flash points and biodegradability of the Nigerian Jatropha oil were not studied.

Figure 1: Determination of specific gravity and density.

2.1.2 Determination of pH of The Oils

The pH values of the oils were measured using the REX pHS -25 model pH meter shown in Figure 2. The pH meter was first calibrated using a standard solution. The electrode of the pH meter was cleaned with distilled water after each reading before taking another reading.

Figure 2: REX pH meter.

2.1.3 Determination of Saponification Value of The Vegetable Oils

The alcoholic KOH was freshly prepared by dissolving KOH pellet in ethanol. More than 1g of oil was measured and poured into a conical flask. 25ml of the alcoholic KOH was added to it, a blank was also used. The sample was well covered and placed in an oven for 30minutes shaking it periodically, 1ml of phenolphthalein was added to the mixture and to the blank and titrated against 0.5M HCl to get the end point. The saponification value (SV) was calculated using Equation (1).

$$SV = \frac{56.1(B - A)N}{W_{oil}} \quad (1)$$

Where,
B = Volume of standard ethanol potassium hydroxide used in blank titration.
A = Volume of standard ethanol potassium hydroxide used in titration with the oil.
N = Normality of standard acid; and W_{oil} = weight of oil used.

2.1.4 Determination of Iodine Value of The Oils

The oil was poured into a small beaker; a small rod was added to it. Between 1to 2g of the oil was weighed and poured into a glass-stopper bottle of about 250 ml capacity. 10ml of carbon tetrachloride was added to the oil to dissolve it. 20ml of Wij's solution was added and a stopper was inserted and allowed to stay in the dark for 30minutes. 15ml of potassium iodide solution (10%) and 100ml of water was introduced and the mixture was thoroughly mixed and titrated with 0.1M sodium thiosulphate solution using starch as indicator (titration = 'A'ml). A blank was also carried out at the same time starting with 10ml of carbon tetrachloride (titration = 'B'ml). The iodine value (IV) was calculated using the Equation (2).

$$IV = \frac{0.1269(B - A)N}{W_{oil}} \times 100 \quad (2)$$

Where,
B = Volume of sodium thiosulphate used in blank titration.
A = Volume of sodium thiosulpate used in titration with oil.
N = Normality of sodium thiosulphate.
W_{oil} = weight of oil used and 0.1269 is the Iodine number.

2.1.5 Determination of Acid Value/ Percentage Free Fatty Acid (%FFA)

2g of the oil was measured and poured into a 250ml beaker. A neutral solvent (a mixture of petroleum ether and ethanol) was prepared and 50ml of it was taken and poured into the beaker containing the oil sample. The mixture was stirred vigorously for 30minutes. 0.56g of potassium hydroxide (KOH) pellet was measured and placed in a separate beaker and 0.1M KOH was prepared, 3drops of phenolphthalein indicator was added to the oil-ethanol-petroleum ether mixture and was titrated against 0.1M KOH till the colour turned pink and persisted for 15minutes. The acid value (AV) was determined using the Equation (3).

$$AV = \frac{56.1 \times V \times N}{Woil} \quad (3)$$

Where;
V = Volume of standard alkali used; N= normality of standard alkali used;
W_{oil} = Weight of oil used

The percentage free fatty acid (%FFA) is gotten from Equation (4).

$$FFA = \frac{AV}{2} \quad (4)$$

2.2 Determination of Rheological and Temperature Properties

The dynamic viscosity at 400C and1000C was determined according to the ASTM D2983 standard. A 2013 model NDJ-5S digital viscometer that measures in the range 10 to 2×10^6 mPas having an accuracy of + 2% as shown in Figure 3 was used.

Figure 3: Measurement of dynamic viscosity.

The viscosity index was determined according to ASTM D2270 standard using Equation (5).

$$V.I = \frac{(L-U)}{(L-H)} \times 100 \quad (5)$$

Where,
V.I is the viscosity index
U is the kinematic viscosity of the oil to be determined measured at 40°C.
L is the kinematic viscosity of the reference oil at 40°C.
H is the kinematic viscosity of the reference oil at 100°C.
The cloud point was measured according to the ASTM D2500. The pour point was determined according to the ASTM D97 standard.

The flash point was measured according to the ASTM D92 standard. 30mls of the oil was poured into an open cup apparatus and heated at atmospheric pressure while the temperature was being monitored with the digital infra-red thermometer. The set up was carried out in a fume chamber where air was being supplied to the heated oil until it ignited. The temperature at which it ignited was noted and recorded as the flash point of the oil.

2.3 Determination of Thermo-Oxidative Stability

The peroxide value is essentially used as the basis for studying the stability of vegetable oils (Demian, 1990). The oxidative and thermal stabilities of the oils were determined by measuring peroxide values of the oils.

The peroxide value was measured according to AOCS C/8 53 standard. 1g of oil was weighed into a clean drying boiling tube, 1g of powdered potassium iodide and 20ml of solvent mixture (2 volume of glacial acetic acid + 1 volume of chloroform) was added, the tube was placed in boiling water so that the liquid boils within 30 seconds and was also allowed to boil vigorously for not more than 30 seconds. The content was quickly poured into a flask containing 20ml of potassium iodide solution; the tube was washed out with 25ml of distilled water and was titrated with 0.02M

sodium thiosulphate solution using starch as indicator. A blank was also carried out at the same time. The peroxide value (PV) was determined from Equation (6).

$$PV = \frac{(A - B) \times N}{Woil} \times 1000 \quad (6)$$

Where,
B = volume of sodium thiosulphate used in blank titration.
A = volume of sodium thiosulpate used in titration with oil.
N = normality of sodium thiosulphate (which is 0.02).
W_{oil} = weight of oil used.

2.4 Corrosion Level Test

The corrosion level of the oils was determined according to ASTM D4627. The experiment was conducted by measuring out 1g of cast iron chips unto a filter paper placed in a Petri dish. Then 2mls of the particular oil collected with a pipette was used to wet the iron chips on the filter paper in the Petri dish and covered for 2 hours. After which the iron chips were thrown away and the filter paper carefully rinsed out with tap water. The paper was treated with acetone and allowed to dry at room temperature, with the corrosion level assessed by sight.

2.5 Biodegradability Test

The test for the biodegradability of the jatropha oil as compared to that of the SAE20/W50 was carried out according to Ijah and Antai (2003). The extent of the degradation of the incorporated oils by Bacillus sp. CDB-08 bacterial isolated from petroleum contaminated soil was determined by gravimetric analysis method. The method involved the extraction of the residual oils with 50 ml petroleum ether and noting its absorbence reading at 520 nm wavelength. The percentage biodegradability of the oils was also determined by weighing the amount of recovered oil at interval of 7 days over a period of 28 days using Equation (7).

$$\%Biodegradation = \frac{(Wao - Wro)100}{Wao} \quad (7)$$

Where,
Wao = weight of the added oil.
Wro = weight of the residual oil after days of bacterial inoculation.

3.0 RESULTS AND DISCUSSION

3.1 Physicochemical Characterization

The physicochemical properties of the Jatropha oil and mineral oil-based lubricant (SAE 20W50) are as shown in Table 2. From the result Jatropha oil has a specific gravity of 0.913 and density of 913 kg/m3, which is slightly higher than the values (0.903 and 903kg/m3) reported by Akbar et al; (2009). Similarly, the specific gravity and density of SAE 20W50 is 0.878 and 878 kg/m3 respectively. The slight differences in the density and specific gravity of Jatropha oil and that reported by Akbar et al; (2009) are as a result of differences in climate and soil conditions where the plants were grown and the condition of test. It also can be seen that the Jatropha oil is

denser than the SAE 20W50 while both oils are less dense compared to water and would therefore float in water.

The acid value of the Jatropha oil is 31.15mg KOH/g and its percentage free fatty acid is 15.6. These values are too high and indicate that the oil is non-edible as the triglycerides in the oil have been decomposed. The lower the acid number the better the oil as a lubricant as the high acid number oil is likely to corrode and wear machine parts that are lubricated. The oil will need modification to bring down its acid value to be a better industrial lubricant.

The saponification value of oil is a measure of the tendency of the oil to form soap during the transesterification reaction. The saponification value obtained for Jatropha oil is 220.46mgKOH/g and is slightly outside the range specified by AOCS. These high saponification value shows that the oil will be more suited for soap and comestic making than for use as a lubricant, thus it may be necessary to modify the oil before it can be used as a lubricant.

The iodine value shows the level of unsaturation of the oil and also influences the oxidation and deposition formed in internal combustion engines. It is used in determining the drying property of the oil. Iodine value obtained for both Jatropha oil and SAE 20W50 were seen to be 88.9gI2/100g and 80.0gI2/100g respectively. The iodine value of Jatropha (88.9 gI2/100g) was seen to be higher than that of SAE 20W50 (80.0 gI2/100g) and this signifies that there is a higher degree of unstauration in the Jatropha oil than in the SAE 20W50, thus both oils are classified as non-drying oils since their iodine value is below 115 gI2/100g.

The pH value is a measure of the acidity or alkalinity of a fluid. The pH of the jatropha oil was 5.82 while that of the SAE 20W50 was 7.12, thus the jatropha oil is acidic but the SAE 20W50 oil is slightly alkaline. It is more desirable for a lubricant to have a pH between 8.0 and 10.0; lubricant with very low or too high pH can be damaging to the skin of the end users. Besides microbial deterioration of biolubricants takes place in acidic medium rather than alkaline medium. The acidic pH of the Jatropha oil will reduce the corrosion protection of the machine components being lubricated thereby reducing their life span thus it is necessary to modify this oil to be suitable for use as a lubricant.

Table 2: Physicochemical Properties of Jatropha Oil and SAE 20W50.

#	Parameter	Jatropha oil	SAE 20W50
1	Specific Gravity	0.913	0.878
2	Free Fatty Acid (mg KOH/g)	15.6	-
3	Saponification Value (mg KOH/g)	220.46	-
4	Acid value (mg KOH/g)	31.15	-
5	Iodine Value (gI_2/100g oil)	88.9	80.0
6	pH	5.82	7.12
7	Density (kgm^{-3})	913	878

3.2 Rheological and Temperature Properties Characterization

The rheological properties (viscosity and viscosity index) of the Jatropha oil and mineral based lubricant (SAE 20W50) are shown in Table 3; while the temperature properties (cloud point, pour point and flash point) are shown in Table 4. Kinematic viscosity is one of the deciding parameters to evaluate the effectiveness of a lubricant. An increase in kinematic viscosity means increase in the lubricating property of the fluid (Rao et al., 2007).

From the results Jatropha oil has a kinematic viscosity of 83.2cSt at 400C while SAE 20W50 has kinematic viscosity of 236.9cSt at 400C. The kinematic viscosity of SAE 20W50 was about

three times that of the Jatropha oil and this means that Jatropha oil has a higher flow capability than the commercial mineral oil SAE 20W50. The Jatropha oil will perform less than SAE 20W50 as a lubricant. However, the SAE 20W50 viscosity at 1000C (99.1cSt) was only slightly higher than that of Jatropha oil at 1000C (63.5cSt). This means that the Jatropha oil has a higher viscosity index than the SAE 20W50, therefore the Jatropha oil will show less variation in viscosity at high temperatures compared to the SAE 20W50. The Jatropha oil conforms to ISO VG 68 grade of industrial oil.

Table 3: Rheological Properties of Jatropha and SAE 20W50.

#	Parameter	Jatropha oil	SAE 20W50
1	Kinematic Viscosity at 40^0C (cSt)	83.2	236.9
2	Kinematic Viscosity at 100^0C (cSt)	63.5	99.1
3	Viscosity Index	145.5	
4	Dynamic Viscosity at 40^0C (mPas)	76	208
5	Dynamic Viscosity at 100^0C (mPas)	58	87

The pour point of the SAE 20W50 (-24.1^{0}C) is very low which is a desirable property, the SAE 20W50 has a lower pour point than that of the Jatropha oil (-11.2^{0}C). Both the Jatropha and SAE 20W50 oils have good cold flow properties (cloud point and pour point), the Jatropha oil meets the cold flow properties standard for lubricants (-6°C for two-stroke engine lubricant as per IS14234 standard). Poor pour point has been what is lacking in most vegetable oils that hinder their applications in systems exposed to low temperatures. Thus, Jatropha oil can be used for lubrication of machines exposed to low temperatures such as automotive engines, construction machines, military and space applications.

The flash point of the SAE 20W50 (255^{0}C) was higher than that of the Jatropha oil (264^{0}C). Both oils have very high flash points which is desirable for a lubricant from the safety point of view. The pour point of the Jatropha oil was slightly lower than that(275^{0}C) reported by Mamuda et al; (2016a), the difference is as a result of the test instruments and procedure used as well as the climatic and soil difference under which the Jatropha were grown. Jatropha oil is safe to be used at high temperatures as lubricant; Jatropha oil has less fire hazard as a lubricant than most lubricanting oils which has flash point of 210°C and fire point about 230°C (Stachowiak, and Batchelor, 2000).

Table 4: Temperature Properties of Jatropha and SAE 20W50.

#	Parameter	Jatropha oil	SAE 20W50
1	Pour point (^{0}C)	-11.2	-24.1
2	Cloud point (^{0}C)	-8.3	-18.9
3	Flash point (^{0}C)	264	255

3.3 Thermo-oxidative Stability Characterisation of Jatropha oil

The peroxide value is the usual method of assessment of primary oxidation products (Gunstone, 2004). Peroxide value of any oil gives an indication of its oxidative and thermal stability. The peroxide value of the Jatropha and SAE 20W50 oil is shown in Table 5. Peroxide value of Jatropha oil was 5.98 meq/kg while that of the commercial mineral oil base lubricant (SAE 20W50) was 0.99 meq/kg. However, this peroxide value of the Jatropha oil is too high showing that the oils have poor oxidative and thermal stabilities.

This result is consistent with the findings of all other researchers that had studied the thermo-oxidative stabilities of vegetable oils (Aravind et al; 2018; Musa et al; 2015; Habibullah et al., 2014; Heikal et al 2016). The poor thermal and oxidation stability of the Jatropha oil implies that lubricants formulated from this oil will have a low shelf life as degradation of the oil will take place very fast. The poor thermo-oxidative stability of Jatropha oil is a major hindrance for its application as industrial lubricants, thus the oil must be modified for it to be useful in the production of industrial lubricants.

Table 5: Thermo-oxidative Stability of Jatropha oil and SAE 20W50.

S/No.	Parameter	Jatropha oil	SAE 20W50
1	Peroxide Value (meq/kg)	5.98	0.99

3.4 Corrosion Inhibition Level of Jatropha Oil and SAE 20W50

The humidified cast iron chippings on filter paper covered in oil in a petri dish is shown in Figure 4(a); while Figure 4(b) is the Jatropha oil filter paper after 2Hrs, and Figure 4(c) shows the SAE 20W50 filter paper after 2Hrs. No rust spot was found on both filter papers containing cast iron soaked in Jatropha oil and SAE 20W50. Thus, both Jatropha oil and SAE 20/W50 exhibits excellent corrosion inhibition characteristics and based on Alves and Oliveira (2008), both Jatropha oil and the SAE 20W50 are of corrosion grade 0.

(a) Test with cast iron particles (b) after 2Hrs, Jatropha oil (c) after 2Hrs, SAE20W50

Figure 4: Corrosion inhibition tests of jatropha oil and SAE 20W50.

3.5 Biodegradability of Jatropha oil and SAE 20W50

The percentage degradation of the jatropha oil and SAE20W50 over a period of 28 days after inoculation with bacterials is shown in Figure 5. The ultra-violet visible (UV-VIS) spectrophotomer absorbence at 520 nm wavelength of the jatropha oil and SAE 20W50 mineral oil over 28 days after inoculation with bacteria is shown in Figure 6.

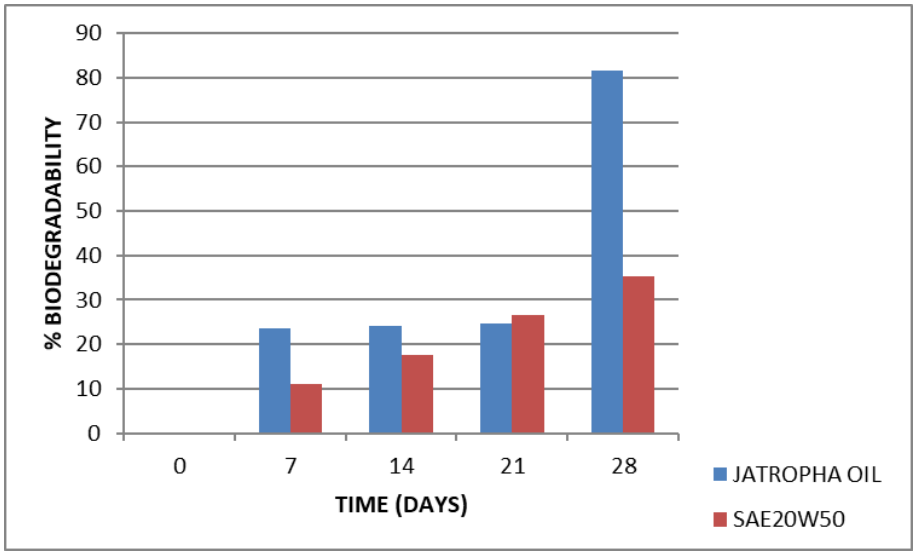

Figure 5: Biodegradability of jatropha oil and SAE 20W50.

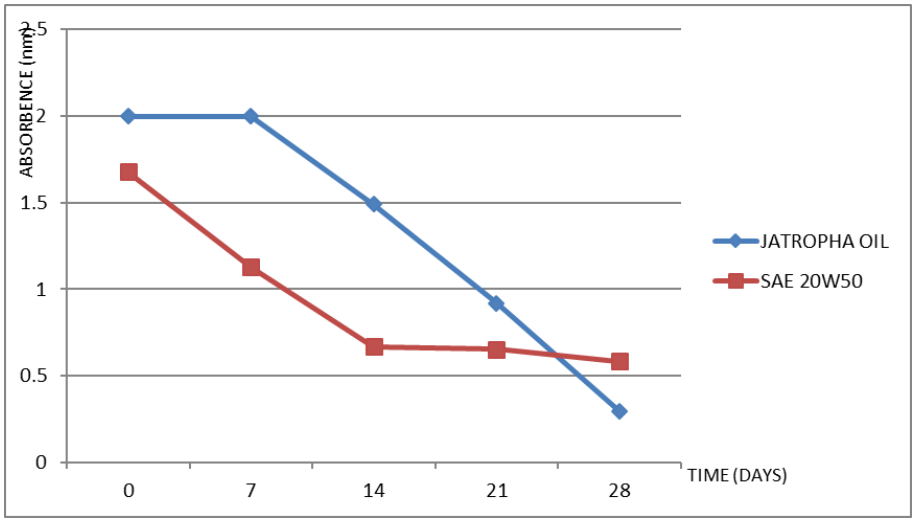

Figure 6: UV-VIS Spectrophotometer absorbency readings of jatropha oil and SAE 20W50.

The absorbance of UV rays by the jatropha oil after 28 days was 0.297 nm while that of the SAE 20W50 after 28 days was 0.583 nm. This indicates that the jatropha oil was more biodegradable than the SAE 20W50, therefore it was eaten up by the bacteria and the solution became less turbid thereby it absorbed less UV rays.

4.0 CONCLUSION

The assessment of Nigerian Jatropha oil for suitability as a base stock for the production of biolubricant has been successfully carried out. Standard laboratory tests were carried out on the Jatropha oil and commercially available mineral oil base lubricant (SAE 20W50) to determine

their physicochemical, rheological, temperature, thermo-oxidative stability, biodegradability and corrosion inhibition properties. The Jatropha oil is acidic, unsaturated and has high saponification and free fatty acid values. There is need to modify the Jatropha oil to reduce its saponification and fatty acid values so as to improve its suitability as a base stock for the production of industrial lubricants.

The Jatropha oil has lower viscosity but higher viscosity index compared to the SAE 20W50. The Jatropha oil in its crude form conforms to the ISO VG68 grade of industrial lubricant oil. Also, the Jatropha oil has excellent cold flow and fire hazard properties that do not require improvement. However, the SAE 20W50 has superior cold flow and fire hazard properties compared to the Jatropha oil.

The Jatropha oil has poor thermal and oxidative stability. The thermo-oxidative stability of the Jatropha oil needs to be improved for it to be suitable a basestock for the production of industrial lubricants. The SAE 20W50 had better thermo-oxidative stability compared to the Jatropha oil. The Nigerian Jatropha oil has excellent corrosion inhibition properties. Both the Jatropha and SAE 20W50 are of corrosion grade 0.

The Nigeria jatropha oil is readily biodegradable while the mineral oil based lubricant SAE20W50 has poor biodegradability. Nigera Jatropha oil therefore offers a solution to the quest for renewable, environmentally friendly lubricant base stock.

ACKNOWLEDGEMENT

The authors wish to thank Mr. Bulus Musa of Water, Aquaculture and Fisheries Department Laboratory, Mr. Aliyu Jagaba, of the Microbiology Laboratory and Mr. Peter Obasa of the Food processing Laboratory, all of the Federal University of Technology Minna, P.M.B.65 Minna, Niger State, Nigeria, for their kind assistance towards the success of this work.

REFERENCES

Adhvaryu, A., & Erhan, S. Z. (2002). Epoxidized soybean oil as a potential source of high-temperature lubricants. Industrial Crops and Products, 15(3), 247-254.

Adhvaryu, A., Liu, Z., & Erhan, S. Z. (2005). Synthesis of novel alkoxylated triacylglycerols and their lubricant base oil properties. Industrial crops and products, 21(1), 113-119.

Ajithkumar, G. (2009). Analysis, modification and evaluation of the cold flow properties of vegetable oils as base oils for industrial lubricants.

Akbar, E., Yaakob, Z., Kamarudin, S. K., Ismail, M., & Salimon, J. (2009). Characteristic and composition of Jatropha curcas oil seed from Malaysia and its potential as biodiesel feedstock feedstock. European journal of scientific research, 29(3), 396-403.

Aluyor, E. O., Obahiagbon, K. O., & Ori-Jesu, M. (2009). Biodegradation of vegetable oils: A review. Scientific Research and Essays, 4(6), 543-548.

Alves, S. M., & de Oliveira, J. F. G. (2008). Vegetable based cutting fluid: an environmental alternative to grinding process. In LCE 2008: 15th CIRP international conference on life cycle engineering: Conference proceedings (p. 664). CIRP.

Aravind, A., Prabhakaran Nair, K., & Joy, M. L. (2018). Formulation of a novel biolubricant with enhanced properties using esterified rubber seed oil as a base stock. Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology, 232(12), 1514-1524.

Arbain, N. H., & Salimon, J. (2010). Synthesis of Jatropha Curcas Fatty Acid Based Trimethylolpropane Ester. Empowering Science, Technology and Innovation towards a Better Tomorrow, 9-15.

Awoyale, A. A., Odubiyi, O. A., & Eloka-Eboka, A. C. (2011). Production and Testing of Biodegradable Grease from Black-Date (Canarium schweinfurthii) Oil (pp. 223-233).

Bartz, W. J. (2006). Ecotribology: environmentally acceptable tribological practices. Tribology International, 39(8), 728-733.

Bilal, S., Nuhu, M., & Kasim, S. A. (2013). Production of biolubricant from Jatropha curcas seed oil. Journal of Chemical Engineering and Materials Science, 4(6), 72-79.

Demian, M. J. (1990). Principles of food chemistry. nd Van Nostrond Reinhold international Company Ltd. London England, 37-38.

Dowson, D., (1998), History of Tribology, Professional Engineering Publication Limited, Bury St. Edmunds, Suffolk, U K.

Erhan, S. Z., and Asadauskas, S., (2000), Lubricant Base Stocks From Vegetable Oils, Ind. Crops Prod., 11: 277-282.

Garba, Z.N; Gimba, C.E; and Emmanuel, P; (2013). Production and Characterisation of Biobased Transformer Oil from Jatropha Curcas Seed, Journal of Physical Science, 24(2), 49–61.

Gunstone, F. D. (Ed.). (2004). Rapeseed and canola oil: production, processing, properties and uses. CRC Press.

Habibullah, M., Masjuki, H. H.,Kalam, M. A.,Ashraf, A. M.,Habib, M. A., and Mobarak, H. M. (2014). Effect of Bio-lubricant on Tribological Characteristics of Steel, Procedia Engineering 90 (2014): 740 – 745

Heikal, E.K., Elmelawy, M.S., Khalil, S.A., and Elbasuny, N.M., (2016).Manufacturing of environment friendly biolubricants from vegetable oils, Egyptian Journal of Petroleum 26 (2017): 53-59

Ijah, U. J. J; and Antai, S.P; (2003). The Potential Use of Chicken-drop Micro-organisms for Oil Spill Remediation. The Environmentalist, 23; 89-95.

Jain, A.K. and Suhane, A. (2012) Research Approach & Prospects of Non Edible Vegetable Oil as a Potential Resource for Biolubricant - A Review, Advanced Engineering and Applied Sciences: An International Journal; 1(1), 23-32.

Lawal, S. A., Choudhury, I. A., & Nukman, Y. (2012). Application of vegetable oil-based metalworking fluids in machining ferrous metals—a review. International Journal of Machine Tools and Manufacture, 52(1), 1-12.

Li, W. and Wang, X. (2015). Bio-lubricants derived from waste cooking oil with improved oxidation stability and low-termperature properties", Journal of Oleo Science, 64(4), 367-374

Mamuda, M., Dauda, M; and Binfa, B.(2016a). Influence of formulated neem seed oil and jatropha curcas seed oil on wire drawing of mild steel and medium carbon steel at elevated temperatures. Jurnal Tribologi 10, pp.16-27.

Mamuda, M; Yawas, D.S; and Dauda, M; (2016b). Assessment of Lubricant Properties of J.Curcas Seed Oil and 10W-30 Arrow Premium Synthetic Blend Plus Oil, International journal of Engineering Science Innovation, 5(3), 10-14.

Mercurio, P., Burns, K. A., & Negri, A. (2004). Testing the ecotoxicology of vegetable versus mineral based lubricating oils: 1. Degradation rates using tropical marine microbes. Environmental Pollution, 129(2), 165-173.

Mohammed, N ; (2008). Synthesis of Biolubricant from Vegetable Oils, MSc. Chemical Engineering Thesis submitted to the Postgraduate School, Ahmadu Bello University Zaria, Nigeria

Musa U., Mohammed I. A, Sadiq M. M., F. Aberuagba., Olurinde O.A and Obamina R (2015) Synthesis and Characterization of Trimethylolpropane-Based Biolubricating Oil from Castor oil, Proceedings of 45th Annual Conference, Exhibition of Nigerian Society of Chemical Engineers (NSChE), Nov. 5-7, 2015, Warri, Delta State, 248-253.

Musa U., Mohammed I. A, Sadiq M. M., Aliyu, M.A., F. Aberuagba., and Adekunle, J. I.(2016). Statistical Optimization of Biolubricant Production from Jatropha Curcas Oil using Trimethylolpropane as a Polyol, Proceedings of the World Congress on Engineering and Computer Science 2016 Vol II WCECS 2016, October 19-21, 2016, San Francisco, USA

Rani, S., Tarun, M.S., Joy, M.L., and Nair, K.P., (2014). Vegetable Oils as Lubricant Base Review, International Journal of Scientific and Engineering Research, 5 (7), 708-710

Rao, D. N., Srikant, R. R., & Rao, C. (2007). Influence of emulsifier content on properties and durability of cutting fluids. Journal of the Brazilian Society of Mechanical Sciences and Engineering, 29(4), 396-400.

Silva, J. A. C., Habert, A. C., & Freire, D. M. G. (2013). A potential biodegradable lubricant from castor biodiesel esters. Lubrication Science, 25(1), 53-61.

Stachowiak, G.W. and Batchelor, A. W., (2000). Engineering Tribology, Second Edition. Butterworth- Henemann, Boston.

Woma, T. Y., Lawal, S. A., Abdulrahman, A. S., MA, O., & MM, O. (2019). Vegetable Oil Based Lubricants: Challenges and Prospects. Tribology Online, 14(2), 60-70.