Synthesis and Study of Properties of Biolubricant based on *Moringa oleifera* Oil for Industrial Application

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Abstract

Blends of Moringa oleifera *oil with conventional lubricant, SAE 40 were studied for industrial application. The* Moringa oleifera *seed oil was extracted using soxhlet extractor. The oil was filtered, degummed and blended with SAE 40 in different percentage from 10% - 40% by volume using a magnetic stirrer. The viscosity and density properties as well as wear rate property using aluminium pin against carbon steel disc were studied. In cases of 40°C and 100°C, viscosity of MOL 10 satisfied SAE 30 and SAE 40 grade requirements. Next to it was MOL 20 which satisfied SAE 30 grade requirement at 40°C and 100°C but did not meet SAE 40 grade requirement at both temperatures. In case of 100°C, the biolubricants MOL 30 and MOL 40 did not meet the SAE requirements. The density of all the blend samples was found comparable to those of the conventional base oil. The wear rate of all blend samples increased with applied load. The MOL 10 blend showed nearly same properties comparable with the base lubricant (SAE 40) in terms of density, viscosity and wear rate, which demonstrated that it would be commercially viable for industrial application.*

Keywords*: Oil extraction, degumming, Moringa-SAE 40 blends, viscosity, density, wear rate.*

Introduction

The growing interest of researchers in green tribology to save energy, enhance the environment and reduce dependency on petroleum base lubricating oils have necessitated the use of certain percentage of renewable-oils in passenger vehicles and machineries. In line with this, Kalam *et al.* (2012) suggested the initiative to pass legislations to use certain percentage of bio-lubricant to reduce the dependency on petroleum based lubricants. Most of the oils which have been used to meet lubricating needs originated from petroleum. However, there are now countless challenges posed by using such oils as lubricants in most of today's application. The recent reality in most countries of dwindling oil reserve, fluctuating prices of petroleum based products, biodegradability, safety and health of operators, informed the need for an ecofriendly lubricating fluids from renewable sources.

The presently marketed vegetable oil based fluids are reasonable substitute to conventional mineral oil-based lubricating oils and synthetic esters (Adhvaryu *et al*. 2005) with performance characteristics and quality comparable, due to their low volatile organic compound (VOC) emissions, high flash point, excellent lubricity, biodegradability and viscosity-temperature characteristics.

Vegetable oils are reported to have better performance during cold extrusion of mild steel (Shamagana 2008) and their frictional characteristics at par with the standard sodium stearate lubricant during steel and copper wire drawing operations (Oche 1992). Recent studies have shown that bio-based lubricating fluids have better lubricities and their viscosities reduce significantly well at high temperature values than the mineral based oils (Ozioko 2012). Vegetable oils with high oleic acids yield stable lubricants that oxidize much more slowly as observed by Castro *et al.* (2006) and have also shown potential in formulation of industrial fluids for high temperature applications (Sharma *et al.* 2009). However, they are not without their own shortcomings. There are challenges of low temperature behavior, oxidation and thermal stability and gumming effect (Mofijur *et al.* 2012; Ponnekanti and Kaul 2012). These characteristics are disadvantages of vegetable oils, in sharp contrast to mineral oil-based fluids (Salimon and Salih 2009). A lot of development and research is being done on vegetable oils to ameliorate these challenges so that they may prove to be a cheap and good substitute of petroleum based lubricants.

Moringa oil is a vegetable oil extracted from the seeds of *Moringa oleifera* tree. *Moringa oleifera* tree known commonly as “Ben oil tree”, “Horseradish tree” or “drumstick tree” in English language is one of the most versatile plants that are also of economic value (Anwar *et al.* 2007). It belongs to 14 species of Moringaceae family and *Moringa* genus as the best known species. The tree is native to India, Pakistan, Bangladesh and Afghanistan, Southeast Asia, South America, Pacific and Caribbean Islands (Iqbal and Bhanger 2006). Its drought resistant capability has spurred its wide distribution in the tropics and in Africa. In Nigeria it is locally known as ‘‘Okire ó Yibo” in Igbo, “Ewe Igbale” or “Adagba maloye” in Yoruba, and “Zogale”, “Gawara” or “Habiwal” in Hausa. It grows more rapidly when found in well-drained soils with ample water, but tolerates sandy soils, heavier clay soils and water limited conditions. A mature Moringa tree height ranges from 5-12 m with an open umbrella-shaped crown, straight trunk (10-30 cm thick) and a corky, whitish bark. The fatty acid composition of moringa oil is given in Table 1.

The use of biolubricant from vegetable oil feedstock can make a positive contribution in improving access to sustainable and affordable lubricants. In this report, moringa oil based biolubricants was developed and the densities, viscosity and wear rate studied to assert its compatibility for industrial application.

Table 1. Fatty acid composition of the moringa oil.

Type of fatty acid	Percentage (%)
Palmitic acid (C16:0)	5.5
Stearic acid (C18:0)	5.7
Oleic acid (C18:1)	73.2
Linoleic acid (C18:2)	1.0
Arachidic acid (C20:0)	3.9
Behenic (C22:0)	6.8
Eicosenoic(C20:1)	2.6

Source: Trakarnpruk and Chuayplod (2012).

Materials and Methods

The materials and equipment used in carrying out this research work include moringa seeds, SAE 40 oil, Soxhlet apparatus, hexane, mortar and pestle, grinder, oven, tray, electronic weighing machine, mesh screen, magnetic stirrer, acetone, glass rod, separating funnel, pin-on-disk machine, carbon steel material and aluminum alloy. The method described by Hassan *et al.* (2006) was used in the determination of the viscosity and specific density.

Methods

Seed processing and oil extraction

The seeds of *Moringa oleifera* collected from Sheda Science and Technology Complex were selected according to their conditions, where damaged seeds and some foreign materials such as ticks, stains, leaves, sand and dirt were discarded before seeds in good condition were cleaned thoroughly with clean water, sun dried in the open, cracked and dehulled to release the kernel embedded inside. The de-hulling was done by cracking moringa seeds using mortar and pestle and a separation of hulls and kernels achieved using tray to blow away the hulls in order to achieve high yield. The dehulled moringa seed was dried in the oven at 35^0C for 2 hours to make the oil extraction easier. The dehulled and heated moringa seed was grounded into particle size (0-0.20mm) using grinder to rupture the cell walls for oil release. The oil was extracted from the ground seeds using Soxhlet extractor fitted with a round-bottomed flask and a reflux condenser. After extraction for 4 h with 150 ml of refluxing *n*-hexane at temperature of 65^0C, the solvent was evaporator and the oil extracted was filtered and degummed.

Degumming of extracted oil

The extracted oil was heated to 75°C on water bath and 20% boiling water was added. The mixture was stirred for 10 min with the aid of a glass rod and allowed to stand in the separating funnel. Thereafter, the aqueous layer was removed. The procedure was repeated to ensure removal of most gums. The viscosity and specific densities of the degummed oil and SAE 40 before and after blending were determined using the method described by Hassan *et al*. (2006).

Preparation of lubricant sample

There were five different types of lubricant samples investigated in this research. The lubricant SAE 40 was used as a base lubricant and comparison purpose. The blended samples were prepared by mixing of 10%, 20%, 30%, and 40% moringa oil in SAE 40. The samples were mixed with the base lubricant using a magnetic stirrer for 20 minutes for homogenization. . The ratio of the percentage of moringa oil to the volume of SAE 40 oil is shown in Table 2.

Table 2. Ratio of the percentage of moringa oil to the volume of SAE oil based on 200 ml.

Blends	Percentage of moringa oil	Vol. of moringa oil	Vol. of SAE 40
MOL 0	0	0.0	200
MOL 10	10	10.0	190
MOL 20	20	20.0	180
MOL 30	30	30.0	170
MOL 40	40	40.0	160

Preparation of pin and disc specimens

The specimens were prepared from carbon steel material and aluminum alloy. The disc was prepared from carbon steel (Fe-2.3%Cr-0.9%C) hardened to 65 HRC and aluminum alloy used to prepare the pins. The pin samples were of 100-mm length and 12-mm diameter, while the disc samples were of 120-mm diameter and 8-mm thick. The same size and shape were used to present uniformity in measurements. Prior to the conduct of test it was ensured that the surfaces of the specimens are cleaned properly with acetone to free the surfaces from dirt and debris.

Determination of wear values

Wear test was carried out on pin-on-disc machine under lubricated condition. The aluminum alloy pin was mounted vertically on a still vice such that its face pressed against rotating carbon steel disc. The holder along with the aluminum alloy pin was positioned at a particular track diameter. A track radius of 40mm was selected for this experiment and was kept constant for the entire investigation. For each test, new aluminum alloy pin, lubricant sample and carbon steel disc were used. Lubricant sample was used to lubricate disc surface. During experiment, the aluminum alloy pin remains fixed and lubricated disc rotates. The aluminum alloy pin and carbon steel disc were removed on completion of each sample testing. The removed pin was cleaned with acetone, dried and weighed to determine the mass loss due to wear. The difference in the mass measured before and after the test gives wear of the aluminum alloy pin. The mass loss of the aluminum alloy pin was measured in an electronic weighing machine with a least count of 0.001 g. The ratio of mass loss to sliding distance was defined as wear rate. The wear test was carried out by varying the load and keeping speed and time constant. The constant values for speed and time used were 600rpm and 3,600 sec, respectively.

Results

The obtained results were based on the studies carried out on the percentage of oil extracted, viscosity, specific density and wear rate.

Discussion

In Table 3, the percentage of oil extracted (42.80%) showed a variation with the report of Anwar *et al*. (2005) and Rashid *et al*. (2008) who reported 35% but falls within the range of (38-45%) found in the literature (Abdulkareem *et al*. 2011). Variation in oil yield may be due to differences in the variety of plant, cultivation climate and the method of extraction used.

Table 3. Determination of percentage oil extracted.

Determination	Value (g)
Weight of empty flask (M_1)	108.5
Weight of Sample (W_1)	35
Weight of empty flask +Oil (M_2)	215.5
Weight of Oil (M_2-M_1)	107
2nd Weight of Sample	50
3-rd Weight of Sample	75
4-th Weight of Sample	100
Percentage of oil extracted	42.80%

The rate of oil resistance against flowing is called viscosity, which is one of the most important factors for selecting suitable oil. Table 4 shows the viscosity grade requirement for the lubricants set by Society of Industrial Engineers (SAE) and International Organization for Standardization (ISO).

Table 4. Properties of typical SAE grade lubricants.

	Viscosity (cSt)		
SAE grade	ISO grade	40^0C	100^0C
30	100	90 -110	9.30 -12.49
40	150	135-165	12.50 -16.29

Source: <http://www.bobistheoilguy.com/viscosity-charts>.

Fig. 1 shows the viscosity of tested different biolubricant blends. Each ISO viscosity grade number corresponds to the mid-point of a viscosity range expressed in centistokes (cSt). The comparison of the results of Fig. 1 with that of SAE grade illustrated that in case of 40°C and 100°C, viscosity of MOL 10 satisfied SAE 30 and SAE 40 grade requirements. Next to it was MOL 20 which satisfied SAE 30 grade requirement at 40°C and 100°C but did not meet SAE 40 grade requirement at both temperatures. In case of 100°C, the biolubricants MOL 30 and MOL 40 did not meet the SAE requirement.

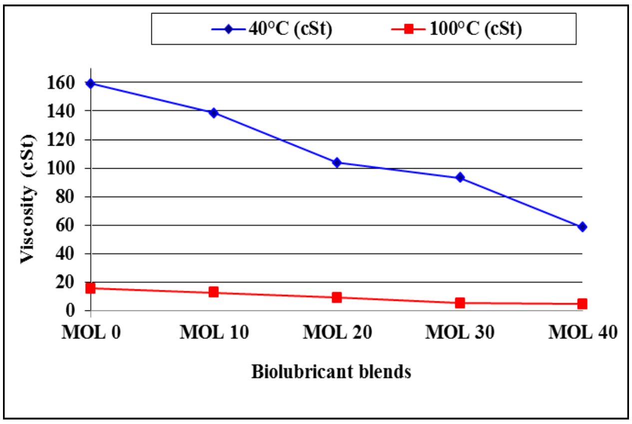

Fig. 1. The viscosity of various blends of biolubricants at 40°C and 100°C.

The SAE 30 was reported to have specific density of 0.895 (Hassan *et al*. 2006). From the experimental results all the blend samples were found to be comparable to those of the base oil as shown in Fig. 2 with minimum of 0.875 for MOL 10 and maximum of 0.894 for MOL 40. An increasing trend in specific density was observed as the percentage volume of moringa oil increased in the blends. This may be due to the high specific density of moringa oil (0.91) compared to the convensional SAE 40 (0.868). The result of the blends specific density are within SAE 30 and SAE 40 values and this showed that all the sample specific densities are acceptable.

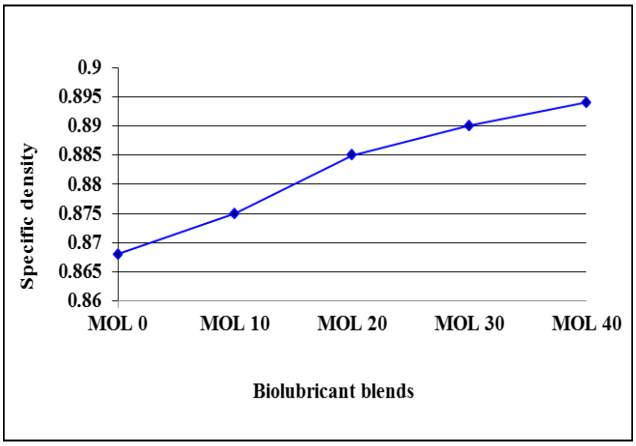

Fig. 2. Effect of blend ratio on the specific density of biolubricant.

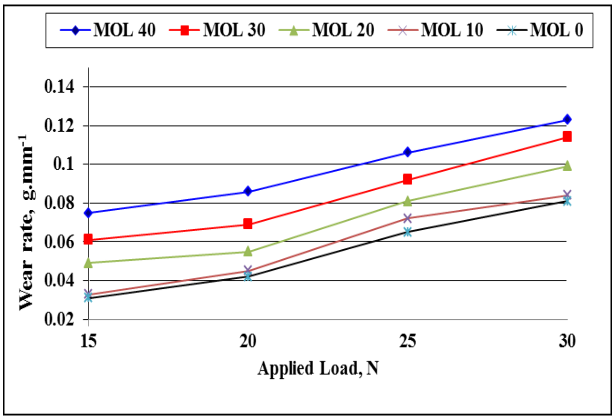

Fig. 3. Variation of wear rate with load for various biolubricants.

Conclusion

Based on the experimental study the following conclusions can be drawn:

- The viscosity of MOL 10 satisfied SAE 30 and SAE 40 grade requirements. Next to it was MOL 20 which satisfied SAE 30 grade requirement at 40°C and 100°C but did not meet SAE 40 grade requirement at both temperatures. The biolubricants MOL 30 and MOL 40 did not meet the SAE requirement at 100°C.
- The wear rates of the biolubricants were different with MOL 10 wear rate comparable with the base lubricant (Fig. 3).
- The specific densities of all the biolubricant samples are within SAE 30 and SAE 40 values.
- The wear rate of all blend samples increased with applied load with MOL 10 biolubricant film having maximum ability to protect metal to metal contact (Fig. 3).

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