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Analysis of Blends of Vegetable Oils with Mineral Based Lube Oil

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Abstract Current energy demand will continue to be on alarmingly increasing level due to urbanization and the use of machineries to aid human operations. While it has become difficult for industrial and technological growth to be achieved without machines and, consequently, use of energy, depletion and associated challenges with the consumption of mineral based sources of energy have necessitated the search for renewable, health and environmental adaptable sources of energy. Blending vegetable oils with SAE 40 lubricating oil will ameliorate concerns for mineral oil sources exhaustion and ecological concerns because vegetable oils based sources are renewable, biodegradable, ecofriendly, and are safe for handling. This study was carried out in order to obtain blends of lubricating oils using vegetable oils and mineral based SAE 40 lube oil. The crude calabash seed oil was extracted from the calabash seeds using Soxhlet extraction method while the crude waste cooking palm oil was obtained after filteration, centrifugation at 500 rpm, and drying over anhydrous sodium sulphate (Na2SO4) crystals overnight. The crude oils were blended with mineral based SAE 40 lubricating oil at the ratio of 10 and 20% (w/w) respectively. The quality parameters of the blends confirmed their potentials to be used for one stroke engine. The blended lubricating oils have qualities that make them suitable for any operations where the mineral based SAE 40 lubricating oil is applicable and therefore, they could be used to reduce consumption of mineral based lube oils.

Keywords Renewable, Vegetable oils, Calabash Seed Oil, Palm Oil, Ecofriendly, Biodegradable

Introduction

The demand for energy is exponentially increasing due to industrial and technological developments, upsurge in human population, and man's quest for a better standard of living [1-3]. The increasing consumption of fossil fuel leads to depletion of the world's energy reserves and its associated environmental challenges [4-6]. Petroleum based oil resource is fast depleting, non-ecofriendly, toxic, and it is not adaptable with the environment [1,3,7-10]; and this has casued interest in lubricants derived from biomass sources [4,11-16]. The declining reserves of mineral based energy sources and the growing regulations for health and environment concerns have made renewable energy sources exceptionally attractive for the future [1-3].

Fats and oil are biomasses that have been found useful in biolubricating processes to produce tailor-made products [17-20]. It is reported that 80% of the world's natural fats and oils come from vegetable oils [20], while 85.00 – 90.00% of the total global lubricant production comes from non-renewable petroleum sources [21].

It has been found that for every kilogram of biodiesel used to replace petroleum diesel fuel, 3.20 kg of carbon dioxide emission will be avoided [22], while Muhammad *et al*. [4] reported that vegetable oil producing plants take more carbon dioxide from the atmosphere during photosynthesis than the amount of carbon dioxide that is added to the atmosphere during burning.

Lubricants act as antifriction media while reducing the risks associated with machine failures and maitaining optimum machine operations. They also facilitate smoother working and are essential for heat transfer, power transmission, and corrosion inhibition in machinery [5,8,23]. Lubricants protect the surfaces from corrosion, reduce wear due to contact, reduce oxidation, prevent heat loss from the surfaces in contact, act as insulator in transformer applications, act as sealing agents, and improve efficiency of machines [3,24,25].

A lubricant is primarily base oil (75.00 – 90.00%) and additive (1.00 – 30.00%) formulated to improve its performance properties such as pour point, viscosity index and oxidative stability [26-28].

Vegetable oil based lubricants are reasonable substitute to mineral based lubricating oils and synthetic esters [2,3,5,6,9] due to their renewability, environmental friendly, biodegradability, less toxic, low prices, superior preformances, excellent lubricity, low volatile organic compound emission, and safety to handle [2,3,5-9,29]. Vegetable based luricating oils are over 95.00% biodegradable and 20.00 – 30.00% degrade faster compared to mineral based lubricating oils [29], but their major drawbacks are their poor low temperature properties, gumming effects, and poor oxidation and thermal stabilities [2,3,7,9].

Vegetable oils essentially consists of triglycerides, especially unsaturated fatty acids with glycerol [7,8,16,30,31]. They also contain free fatty acids (FFAs) with water and other impurities [3,5,6]. Water is responsible for degradation of oils and additives via hydrolysis and ester-based lubricanting oils are susceptible to attack by water resulting in the production of acids and alcohol [3]. Common pretreatment for the conversion of vegetable oils to biolubricants is esterification of the free fatty acids with methanol in the presence of acidic catalysts [30,32-35]. Blending has also been tested to improve the flash point, pour point, viscosity and oxidative stability of vegetable oil based biolubricants [6,17,24,29].

Ozioko [9] investigated the properties of blended Moringa *oleifera* oil with conventional SAE 40 lubricant from 10.00 – 40.00% by volume using magnetic stirrer. It was found that at 40 and 100^{o}C, viscosity of MOL 10 (Moringa *oleifa* lubricant) satisfied SAE 30 and SAE 40 grades requirements, while MOL 20 satisfied SAE 30 but not the SAE 40 grades. The densities of the blended samples were comparable to those of the mineral base oils; and the wear rate increased with applied load. It was concluded that MOL 10 blend could be commercially viable for industrial application since it showed comparable properties to SAE 40, in terms of density, viscosity and wear rate.

Kailas *et al.* [36] analysed the lubrication properties of different vegetable oils, at different temperatures and found that the lubricating properties of oil, such as, cloud point, pour point, flash point, fire point and percentage carbon residues, change with changing vegetable oil blends. Yashvir [37] studied the friction and wear characteristics of pongamia oil blended lubricant at different load and sliding distance using pin-on-disc tribometer at 3.8 ms^{-1} sliding velocity and applied load of 50, 100, 150 N. A blend of the biolubricant at a ratio of 15, 30, and 50% by volume with the base lubricant SAE 20W-40 were carried out and it was found that the lubrication regime occurred during the test was boundary lubrication while the main wear mechanisms were abrasive and the adhensive wear. It was concluded that pongamia oil in the base lubricant acted as very good lubricant additive that reduced the friction and wear scar diameter during the test.

In a similar investigation, Cygnus Wear Testing Machine was used by Shababuddin *et al.* [7] to investigate the friction and wear characteristics of Jatropha based biolubricant. SAE 40 lubricating oil was used as the reference oil with blend of 10, 20, 30, 40, and 50% Jatropha oil; load of 30 N at 2000 rpm for 1 hour. It was found that the lubricating regime that occurred during the experiment was boundary lubrication while the abrasive and adhesive wears were the main wear mechanisms that occurred in the test. It was concluded that 10% Jatropha oil addition to the mineral SAE 40 based lube oil can be used as lubricating oil without any disadvantage and this will help to minimixe the global consumption of petroleum based lubricants.

Furthermore, friction and wear characteristics of Jatropha oil blended SAE 40 based lube oil was studied by Imran *et al.* [8]. In this experiment, 10, 20, 30, 40, and 50% by volume of Jatropha oil were blended with SAE 40 lubricating oil, and it was found that 10% blended biolubricant gives lowest wear and creates less amount of heat than other blends.

Calabash (*Lagereria sincereria*) is an ornamental plant largely found in Northern Nigeria. A vine that is grown for its fruits which can be used as bottle, utensil or pipe, when harvested dried. [5,38-41]. After processing, few quantity of the calabash seeds are preserved for planting, while the rest non-edible seeds are wasted [5] though oil extracted from calabash seeds is proven to be useful base oil for the synthesis of biodiesel [41] and subsequently, biolubricant [5].

The unused remain of palm oil after cooking or frying is called waste cooking palm oil (WCPO). Waste cooking palm oils are less expensive than fresh palm oils and are promising feedstocks for the production of biolubricants [3,31,32,34,42-44]. The WCPO are generally found around eateries, food industries and restaurants around the world [3,30,31,34] and are potential sources of animal feeds, biolubricant productions, and soap manufacturing [32,42].

This investigation is targetd at blending vegetable oils with the conventional SAE 40 lubricating oil thereby reducing the global consumption of mineral based lubricating oils.

Materials and Methods

Sample Collection and Treatment

The Calabash (Lagenaria *siceraria*) seeds were purchased from Sokoto Central Market, Sokoto, Sokoto State, Northern Nigeria, and were dehulled, dried, and grounded into powder of various sizes and sieved to obtain a homogeneous powder. The sample (300.00 g) was weighed and preserved for oil extraction [5,6,40].

The waste cooking palm oil (WCPO) was collected from Owuna Catering & Restaurant Services, Ikor-Ochekwu, Apa Local Government Area, Benue State, North Central, Nigeria. The particles of salt, pepper and spices in the WCPO were removed by filtration, and the sample was centrifuged at 500 rpm, dried over anhydrous sodium sulphate, Na_2SO_4, crystals overnight (Na_2SO_4 forms clumps when it absorbs water). The crystals were removed by decantation. The waste cooking palm oil (WCPO) was mixed with n-hexane (1:3 oil/n-hexane v/v) to remove the remaining impurities [3,30].

Extraction of Calabash Seed Oil

A Soxhlet extractor was set up with n-hexane as the extracting solvent in round-bottom flask (500 $cm^{3)}$. The powdered sample (200.00 g) was placed in a thimble. The volume of the n-hexane that was used was determined by the ratio 6:1 (w:w% of solvent and sample). The solvent was boilied gently (using heating mantle), a reflux condenser was fitted (to cool the hot solvent), the mixture was digested at 60^0C for 5 hours, while the condensed hot-solvent soaked the thimble containg the sample. The solvent siphoned into the flask when it reached the top of the siphon tube of the the Soxhlet apparatus. The resulting oil and solvent mixture was filtered to remove the suspended solids [4,15,45]. The mixture was placed in a rotory evaporator to evaporate the solvent and thus, calabash seed oil (CSO) was obtained for subsequent analysis.

Blending of Vegetable Oils with SAE 40 Lubricating Oil

The mineral based SAE 40 lubricanting oil was used to blend with the CSO and WCPO. The blending was done for the purpose of comperism of the physicochemical prpoerties of the blends with that of SAE 40 and blends are to be used as possible replacements for the mineral based SAE 40 lubricating oil.

The blended samples were prepared by mixing 10 and 20% (wt) of CSO or WCPO with SAE 40 using a magnetic stirrer for 15 minutes at 40^oC and 600 rpm for homogenisation [9].

Physicochemical Characterisation of the Oils

The vegetable oils, the produced biolubricants, and the blends were analysed for their physicochemical properties as detailed below:

Determination of Kinematic Viscosity of the Blends

The blended oil was poured into a viscometer and mounted upright in the viscometric bath (maintained at 40 or 100^oC). The sample in the tube was allowed to stabilise for 15 minutes. When the equilibrium temperature was attained, the sample level was adjusted, using a suction pump, to 7 mm above the upper mark of the viscometer tube. The time taken for the oil to move from the upper mark to the lower mark of the viscometer tube was recorded. The test, which is in accordance with ASTM D-446, was also carried out for all the blended oils [3,46]. The kinematic viscosity (KV) was calculated using equation 2:

$$KV\ (cSt) = c\ (cSt\ s^{-1})\ \times\ t\ (s) \qquad (2)$$

Where, **KV** is the kinematic viscosity

C is the calibration constant of the viscometer

t is the time taken for the oil meniscus to move from the upper timing mark to the lower timing mark of the viscometer tube.

Determination of Viscosity Index

Viscosity index (VI) of the oil sample was obtained using values of kinematic viscosity obtained at 40 and 100^{o}C with standard measurement table as determined by ASTM D-2270.

Determination of Pour Point

The pour point test of the blends were conducted according to the method discribed in ASTM D-97 with accuracy of ±3^{o}C with the pour point tester. The tester has a minimun temperature of -68^{o}C with methanol as cooling agent. The oil sample (45 cm^3) was poured into a test jar to the levelled mark. Then the tester was cooled to -37^{o}C. While cooling the tester, the oil jar was heated to 45^{o}C using a water bath. The oil jar was cooled with another water bath to a temperature of 27^{o}C. When the pour point tester had reached -36^{o}C, the oil jar was placed in a horizontal position in the hole at the top of the tester and the pour point temperature was taken after 5 seconds when the oil sample showed no movement [3].

Results

Figure 1: A set up for the calabash seed oil extraction unit (SERC)

Figure 2: Analyses of Oils in Progress at OVH Energies & Marketing, Kaduna, Nigeria

Table 1: Results of Properties of the Oils

Oils	KV @100°C (cSt)	KV @40°C (cSt)	VI	PP (°C)
SEA 40	14.50±1.00	147.13±0.33	98±1.00	-12±1.21
Crude CSO	6.24±0.10	21.74±0.02	266±0.00	-10±0.01
Crude WCPO	8.26±0.03	36.98±0.01	206±0.11	-9±0.00
CSO B10	10.50±0.13	63.20±0.14	159±1.20	-22±0.10
CSO B20	10.60±0.22	60.40±0.21	170±0.15	-26±0.21
WCPO B10	8.20±0.44	43.90±0.33	149±0.11	-17±0.00
WCPO B20	8.90±0.07	50.10±0.06	153±0.24	-20±0.01

Discussion

The measure of oil internal resistance to its flow is viscosity [3,9] and is used in the identification of lubricating oil grades and monitoring the changes occurring in the oils while in services [47]. Viscosity is the most important property of lubricating oil [1,7,23]; and higher viscosity is an indication of deterioration by oxidation or contamination, while a decrease in viscosity suggests dilution by fuels [1,3]. The viscosities of blended biolubricants are presented in Table 1. It was observed that the kinematic viscosity of CSO biolubricant increases at 100^{o}C with increasing blending ratio from 10.00 – 20.00% (wt) but decreases at 40^{o}C with increasing blending ratio from 10.00 – 20.00% (wt), while that of WCPO biolubricant increases with increasing blending ratios from 10.00 – 20.00% (wt) at both 40 and 100^{o}C (Table 1). This suggests that as more of WCPO biolubricant is being added to SAE 40 at 40 and 100^{o}C, the viscosities of the blend will increase. In another review, Ozioko [9] who worked on the blends of 10, 20, 30, and 40% (wt) of moringa biolubricant with SAE 30 and SAE 40 and reported that the viscosity of MOL10 (moringa oil lubricant) satisfied SAE 30 and SAE 40 grade requirements at both 40 and 100^{o}C while that of MOL20 satisfied SAE 30 grade requirements at 40 and 100^{o}C but not meet SAE 40 grade requirements at both temperatures. The blended CSO and WCPO have comparable viscosities with that of SAE 40 lubricating oil and therefore, can replace SAE 40 lube oil in any application.

Viscosity index of any lubricating oil is inversely proportional to its temperature and, therefore, a machine using such oil and operates over a higher temperature range requires that such oil has a high viscosity index [3,28]. Viscosity indices of the blended lubricants are presented in Table 1. The trend suggests that the higher the ratio of vegetable oils with SAE 40, the higher the VIs of the blended oils. The reason is that the control SAE 40 is viscous enough to change at higher temperature range and adding an oily material makes its viscosity index to be much higher than what is used as a control. From the result obtained on the blended lubricants, it can be inferred that they have the potential to be used as a lubricant for a one stroke engine.

Pour point of oil is an important parameter that should be considered for an operation in cold environment or equipment that handles cold fluid [1,3]. At low temperature, the viscosity of oil sample will be very high and therefore, causing the oil to resist flow. The temperature at which oil just ceases to flow when cooled at specified rate in standard apparatus is the pour point of that oil [36]. The pour points of the blended lubricants are presented in Table 1 and are shown to decrease with increasing ratio of the vegetable oils in the blend. Arianti & Widayat [48] reteirated that vegetable oils with more double bonds in their chains will have lower pour points compared to those with fewer double bonds. The pour points of the blended oils are lower and will present no problem in very low temperature conditions unlike the SAE 40 lube oil.

Conclusion

The aim of this study was to obtain lubricating oils that are blends of vegetable oils and mineral SAE 40 based lube oil. The viscosities and other parameters of the blended lubricating oils suggest their usefulness for one stroke engine. The study therefore, concludes that 20% (w/w) of vegetable oils blended with conventional mineral based engine oils is suitable for any operations where the SAE 40 lubricating oil is applicable and will reduce consumption of mineral base oil and the associated environmental and health issues.

Recommendations

The following recommendations are made on the blends of vegetable oils with SAE 40 lubricating oil to be used for one stroke engine, though the authors are incorporating some of these recommendations in their ongoing researches on engine oils:

i. Other tests on friction and wear, and thermal and oxidative stabilities should be done on these blended lube oils in order to ascertain their oxidative stability, thermal stability, and usefulness in extreme pressure and temperature conditions during operations.
ii. Exploring the use of tribometer in testing the performance of the blended lube oils
iii. Analysing the blended oils after testing in a generator or lawn mower for quality parameters to decide on the extent of contamination, wear, and shear characteristics of the blended stocks

Nomenclature

ASTM American Standard for Testing and Materials
CSO Calabash Seed Oi
FFA Free Fatty Acids
KV Kinematic Viscosity
MOL Moringa *oleifa* Lubricant
Na_2SO_4 *Sodium Sulphate*
PP *Pour Point*
SAE Society of Automotive Engineers
SERC *Sokoto Energy Research Centre*
VI Viscosity Index
WCPO Waste Cooking Palm Oil
w/w *Weight/Weight*

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