Extraction and Characterization of Soybean Oil Based Bio-Lubricant

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Abstract

Renewable oils are now acknowledged as having the potential to provide the major part of the lubrication provisions of the future. This work is on the possibility of producing bio-lubricant with soybean seeds as a case study. Solvent extraction process using normal hexane was used. Proximate properties such as moisture, volatile matter, ash, fixed carbon content and physical properties such as viscosity, flash/fire point, pour point and density were analyzed. The percentages of the moisture, volatile matter, ash, and fixed carbon content in the soybean seed are 7.95, 72.27, 6.08 and 13.70%. The flash/fire points of the crude soybean is 310°C/320°C, while the pour point value is -7°C. Conversely, the flash/fire points of the heavy duty oil (SAE 40) and light duty oil (SAE 30) are 260°C/300°C and 243°C/290°C, respectively, with corresponding pour points of 9°C and 21°C. It was discovered that the crude soybean oil sample exhibits a good base as a bio-lubricant.

Keywords: *Renewable oil, flash point, fire point, pour point, density, viscosity.*

1. Introduction

An interesting recent development is a growing realization that bio-lubricants present practical alternatives to petroleum-based lubricants. The rising of the prices of petroleum based products, ban by some countries in the use of non-biodegradable lubricants in applications where oils are lost into the soil and surface water, and depletion of oil reserves have necessitated the replacement of petroleum-based oils with less polluting and easily available renewable bio-lubricants for lubrication purpose. Fossil fuels such as petroleum, coal and natural gas, which have been used to meet the energy needs of man, are associated with negative environmental impacts such as global warming (Munack *et al.* 2001; Saravanan *et al.* 2007). Besides, supply of these non-renewable energy sources is threatening to run out in a foreseeable future (Sambo 1981; Munack *et al.* 2001). It has been widely reported that not less than ten major oil fields from the 20 largest world oil producers are already experiencing decline in oil reserves.

The contact pressures between devices in close proximity and moving relative to each other are usually sufficient to cause surface wearing, frictions and generation of excessive heat without protector (Hassan *et al*. 2006). These friction, wear and excessive heat have to be controlled by a process or technique called lubrication. Lubrication is the process or technique employed in reducing wear or tear of one or both surfaces in close proximity and moving relative to each other by interposing a substance called lubricant between the surfaces to carry or help carry the load between the opposing surfaces (Hassan *et al*. 2006; Parsons 2007). A lubricant may be in gaseous, liquid, semi-solid (grease) or solid form (graphite). Because of the importance and wide application of lubrication, coupled with the ever increasing world energy crisis, there is need to source out lubricants other than the conventional ones obtained from mineral oils (Hassan *et al*. 2006; Joy and Wibberley 1979; Francis and Peters 1980)

Soybean oil is a vegetable oil extracted from the seeds of the soybean (*Glycine max*). Vegetable oil lubricants are biodegradable and non-toxic, unlike conventional mineral based oils (Thames and Yu 1999). Low temperature study has also shown that most vegetable oils undergo cloudiness, precipitation, poor flow, and solidification at -10°C upon long-term exposure to cold temperature (Schuster *et al.* 2008) in sharp contrast to mineral oil-based fluids. A reviewed study showed that all bio-based fats, oils and their derivatives had better lubricities than diesel fuel (Fernando *et al.* 2007). Better performance of palm oil based lubricating oil in terms of wear, and that of mineral oil based lubricating oil in terms of friction was also observed (Masjuki *et al.* 1999).

This work considered one alternative of producing a bio-lubricant from vegetable oil with specific emphasis on soybean oil obtained from soybean seeds. In determining whether this will be possible or not, this paper aimed at the following objectives:

• extraction of soybean oil from soybean seeds through solvent extraction process; and

• proximate and physical characterizations.

The proximate properties such as moisture, volatile matter, ash, fixed carbon content and physical properties such as the viscosity, flash point, fire point, pour point and density were analyzed.

2. Materials, Equipment and Methods

The materials and equipment used in carrying out this work include raw soybean seeds, soxhlet apparatus, mortar and pestle, grinder, hexane, flask (round and flat bottom), tray, SAE (Society of Automotive Engineers Warrendale, PA, USA) 30 light duty oil, SAE 40 heavy duty oil, open cup viscometer, ice block, water, stopwatch, beakers (graduated), retort stand, weighing equipment, cleave land open cup apparatus, thermometer, gas burner, viscometer bath, holding cylinder, heater, separating funnel and torch nozzle.

2.1 Methods

2.1.1 Soybean Processing: The soybeans undergo various processing in the course of their preparation for oil extraction. Soybean seeds were purchased from a local market at Bosso town, Minna, Niger State, Nigeria. The seeds were selected according to their condition where damaged seeds and some foreign materials were discarded before seeds in good condition were cleaned thoroughly with clean water, sun dried in the open, cracked and de-hulled. The de-hulling was done by cracking the soybeans using mortar and pestle and a separation of the hulls and cracked soybeans was achieved using a tray to blow away the hulls in order to achieve very high yield. The de-hulled soybeans were heated to 105°C for 35 min to coagulate the soy proteins to make the oil extraction easier. The de-hulled and heated soybeans were grounded into powder using a grinder prior to extraction in order to weaken or rupture the cell walls to release soy fat.

2.1.2 Operation of Soxhlet Extractor: 300 ml of normal hexane was poured into round bottom flask. 10 g of the crushed sample was placed in the thimble made from thick filter paper and was inserted in the centre of the extractor. The soxhlet equipped with a condenser was placed onto a flask containing the hexane. The soxhlet was heated at 60°C. When the solvent was boiling, the solvent vapour travels up a distillation arm and floods into the chamber housing the thimble of solid. The condenser ensures that any solvent vapours cools, and drips back down into the chamber housing the solid material. The extract seeps through the pores of the thimble and fills the siphon tube, where it flows back down into the round bottom flask. This was allowed to continue for 30 minutes. It was then removed from the tube, dried in the oven, cooled in the desiccators and weighed again to determine the amount of oil extracted (Akpan *et al.* 2006). Further extraction was carried out at 30-minute interval until no weight difference was recorded. The experiment was repeated by placing 15g of the crushed sample into the thimble again and the process repeated. At the end of the extraction, the resulting mixture containing the oil was heated to recover solvent from the oil (Akpan *et al*. 2006).

2.1.3 Characterization of Soybean Seeds: Proximate analysis was used to characterize the raw soybean seeds. The proximate analysis determines the moisture, volatile matter, ash, fixed carbon content in the soybean.

2.1.3.1 Determination of Moisture Content: 30 g of the cleaned soybean seeds was taken in a crucible and dried in an oven at a temperature of 105°C for 6 hours and the weight was taken after every 2 hours. The procedure was repeated until a constant weight was obtained. After each 2 hours, the sample was removed from the oven and cooled in desiccators for 30 minutes. It was then removed and re-weighed (Akpan *et al.* 2006). The percentage loss of weight gave the percentage of moisture in the sample. The percentage of moisture content is computed as

$$\%_{MC} = 100 \times \frac{[Wt_0 - Wt_d]}{Wt_0}, \qquad (1)$$

where Wt_0 is the original weight of the sample taken and Wt_d is the weight of the sample after drying.

2.1.3.2 Determination of volatile matter: The dried sample after moisture removal was taken in a crucible and placed in electrically heated oven at a temperature of 920°C for 10 minutes and then cooled in desiccators for 30 minutes. It was then removed and re-weighed. The percentage of weight loss gave the volatile matter content. The percentage of volatile matter is computed as

$$\%_{VM} = 100 \times \frac{[Wt_d - Wt_2]}{Wt_0}, \qquad (2)$$

where Wt_2 is weight of the sample due to the removal of volatile matter.

2.1.3.3 Determination of Ash Content: The remaining sample after determination of volatile matter was kept in furnace at a temperature of 700°C for 2 hours. The percentage of weight loss gave the ash content. The percentage of ash is computed as

$$\%_{Ash} = 100 \times \frac{[Weight\ of\ ash\ left]}{Wt_0}. \qquad (3)$$

2.1.3.4 Determination of fixed carbon: The percentage of fixed carbon is computed as

$$\%_{Carbon} = 100 - \%\ of\ (moisture+volatile+ash). \qquad (4)$$

2.1.4 Determination of the Percentage of Soy Oil Extracted: 35 g of ground sample was placed in the thimble and about 150 ml of normal hexane was poured into the round bottom flask. The apparatus was heated at 60°C and allowed for 2 hours in soxhlet apparatus. Extraction was carried out at 30-min interval until no weight difference was recorded. The experiment was repeated for different sample weights of 40, 45 and 50 g. The resulting mixture in the flask containing the oil was further subjected to evaporation and then cooled in the desiccators. At the end, the weight of oil extracted from 170 g of ground sample was measured. Separating funnel was used to remove insoluble gums (phosphatids) formed, and higher specific gravity ensured its simple separation with separating funnel. The result was expressed as the percentage of oil in the ground sample.

2.1.5 Characterization of the Extracted Soybean Oil: Standard methods were used to characterize the physical properties of the oil, which include the viscosity, flash/fire point, pour point and specific gravity. Conventional sample lubricant was collected and similar tests were conducted to compare the obtained results.

3. Results

The obtained results were based on the proximate and physical property analyses carried out on the samples. Equations (1), (2), (3) and (4) were used in calculating the values shown in Table 1.

4. Discussion

The proximate analysis of raw soybean seed is given in Table 1 which shows that the raw soybean seed contains higher percentage of volatile matter and lesser amount of moisture and ash contents.

In Table 2, the percentage of oil content, 18.25%, shows a variation from the report (Gunstone 1994) who reported 18.35% and falls within the range of the percentage oil content (18-20%) found in the literature (Langstraat 1976). From the flash/fire points test results obtained, it was seen that the flash point of the crude soybean oil was 310°C and the fire point was 320°C. On the other hand, the flash/fire points of the Heavy duty oil (SAE 40) and Light duty oil (SAE 30) was 260°C/300°C and 243°C/290°C, respectively.

Table 3 presents the properties of the various samples considered for the physical properties. It is rather clear from Table 3 when comparing SAE 30 and SAE 40 lubricants that the crude soybean oil has very good flash/fire points. The pour points of the samples are -7°C for the crude soybean oil while 9°C and 21°C for SAE 40 and SAE 30, respectively. The results in Table 3 also show that the flash point for the crude soybean oil is far above that of the SAE 30 and SAE 40 though the fire points are close when compared. The relatively larger flash/fire points of the crude soybean oil can help in safe conservation and transportation.

Table 1. Proximate analysis of raw soybeans.

Raw material	Moisture content (%)	Volatile matter (%)	Ash content (%)	Fixed carbon (%)
Soybean seed	7.95	72.27	6.08	13.70

Table 2. Determination of percentage oil extracted.

Determination	Value (g)
Weight of empty flask (M_l)	108.5
weigh of sample (W_1)	35
Weight of empty flask + oil (M_2)	139.53
Weight of oil (M_2-M_1)	31.03
2nd weight of sample	40
3rd weight of sample	45
4th weight of sample	50
Percentage of extracted oil	18.25%

Table 3. Physical properties of samples and their values.

Sample properties	Crude soybean oil	Light duty oil (SAE30)	Heavy duty oil (SAE40)
Flash point (°C)	310	243	260
Fire point (°C)	320	290	300
Pour point (°C)	-7	21	9
Specific density (mg/ml)	0.830	0.895	0.868
Viscosity at 40° (cst)	29.37	104.00	159.20
Viscosity at 100°C (cst)	6.06	12.00	15.87

Since the pour point is the minimum temperature at which the oil can flow, the implication of this is that the crude soybean oil could be used both in humid and temperate regions. Accordingly, it will be acceptable to say that the samples under consideration have pour points that satisfy their use as lubricating oils.

The density of the samples was conducted to determine the compatibility of the samples. The results showed that the crude soybean oil, heavy duty (SAE 40) and light duty (SAE 30) have densities of 0.830, 0.868, and 0.895 mg/ml, respectively. The results indicate that the crude soybean oil has a good value of specific gravity and will help in case of contamination with water.

The result of viscosity which shows the response of oil to heat and flame under controlled conditions is also shown Table 3. The viscosity of the samples was determined when the operating temperatures were 40°C and 100°C, respectively. Difference was observed between the values obtained for the viscosity of the the crude soybean oil and conventional lubricants (SAE 40 and SAE 30). It was seen that the crude soybean oil at 40^{o}C and 100^{o}C had viscosities of 29.37/6.06 cst (centistokes). This indicates a decrease of 79% which when compared with the conventional lubricants showed a decrease of about 90% and 88% for the heavy duty (SAE 40) and light duty (SAE 30), respectively. This percentage decrease in viscosity shows that as the temperature is increased from 40 to 100°C the viscosity of the crude soybean oil reduces by 79%. The viscosity of the crude soybean oil is more stable than the conventional lubricants. That means the change of viscosity is small by the influence of temperature and thus satisfy their use as lubricating oils.

5. Conclusion

Proximate analysis of raw soybean seeds 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 percentages of the moisture, volatile matter, ash, and fixed carbon content in the soybean seed are 7.95, 72.27, 6.08 and 13.70%.
- The percentage oil content of soybean seed was found to be 18.25%.
- The flash/fire point of 310°C/320°C for the crude soybean oil was obtained. This value is in line with those obtained from both light duty oil (SAE 30) and heavy duty oil (SAE 40) with flash/fire points of 243°C/290°C and 260°C/ 300°C, respectively.
- The pour point of -7°C for the crude soybean oil compared with that of light duty

(SAE 30) and heavy duty oil (SAE 40) which had a pour point of 21°C/9°C.

- The specific density of 0.830 mg/ml for the crude soybean oil conforms to those of Light duty (SAE 30) and Heavy duty (SAE 40) with values of 0.895 mg/ml and 0.868 mg/ml, respectively. It is obvious that the crude soybean oil has good density value. Henc, 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 samples decreased with increase in temperature. This was best with the light duty (SAE 30) which decreased from 104 cst to 12 cst while the crude soybean oil had viscosity of 29.37/6.06 mg/ml at 40°C and 100°C. The heavy duty (SAE 40) had a viscosity of 159.20 mg/ml at 40°C and 15.87 mg/ml at 100°C. On increasing the operating temperatures from 40°C to 100°C, the samples analyzed showed various percentage decreases in their viscosities. The crude soybean oil showed decreases of 79% on increasing the operating temperatures.
- During solvent extraction of soybean oil, insoluble gums were formed and could be the result of hydrated phosphatids in the process.

6. References

Akpan, U.G.; Jimoh, A.; and Mohammed, A.D. 2006. Extraction, characterization and modification of castor seed oil. Leonardo Journal of Sciences 5(8): 43-52, January-June. Available: <http://ljs.academicdirect.org/A08/43_52.pdf>.

Fernando, S.; Hanna, M.; and Adhikari, S. 2007. Lubricity characteristics of selected vegetable oils, animal fats and their derivatives. Appl. Engin. Agric. 23(1): 5-11.

Gunstone, F.D. 1994. The Chemistry of Oils and Fats: Sources, Composition, Properties and Uses. Blackwell Publishing Ltd, London, UK.

Hassan, A.B.; Abolarin, M.S.; Nasir, A.; and Ratchel, U. 2006. Investigation on the use of palm olein as lubrication oil. Leonardo Electronic Journal of Practices and Technologies 5(8): 1-8, January-June. Available: <http://lejpt.academicdirect.org/A08/01_08.pdf>.

Joy, D.C.; and Wibberley, E.J. 1979. A Tropical Agriculture Handbook. Cassell Ltd., London, UK.

Langstraat, A. 1976. Characteristics and composition of vegetable oil-bearing materials. J. Amer. Oil Chem. Soc. 53(6): 241-7.

Masjuki, H.H.; Maleque, M.A.; Kubo, A.; and Nonaka, T. 1999. Palm oil and mineral oil based lubricants - their tribological and emission performance. Tribol. Int. 32(6): 305-14.

Munack, A.; Schröder, O.; Krahl, J.; and Bünger, J. 2001. Comparison of relevant exhaust gas emissions from biodiesel and fossil diesel fuel. CIGR J. Sci. Res. Dev. 3: EE 01- 001. Available: <http://ecommons.library.cornell.edu/bitstream/1813/10240/1/EE%2001%20001%20Munack%20Revised.pdf>.

Parsons, G.M. 2007. Biodiesel and Engine Lubrication. Part 2. Califonia, Chevron Products Company, San Ramon, CA, USA. Available: <http://www.ehwolf.com/Oct_07_Lubrication_Mag_P2_%28biodiesel%29.pdf>

Francis, W.; and Peters, M.C. 1980. Fuels and Fuel Technology: A Summarized Manual. Pergamon Press, Oxford, UK. Pp. 251-66.

Sambo, A.S. 1981. Renewable energy technology in Nigeria: resource availability and potential for application to agriculture. J. Agric. Technol. 3(1): 1-4.

Saravanan, S.; Nagarajan, G.; Rao, G. Lakshmi Narayana; and Sampath, S. 2007. Feasibility study of crude rice bran oil as a diesel substitute in a DI-CI engine without modifications. Energy for Sustainable Development 11(3): 83-92.

Schuster, H.; Rios, L.A.; Weckes, P.P.; and Hoelderich, W.F. 2008. Heterogeneous catalysts for the production of new lubricants with unique properties. Applied Catalysis A: General 348(2): 266-70.

Thames, S.F.; and Yu. H. 1999. Cationic UV-cured coatings of epoxide-containig vegetable oils. Surf. Coat. Technol. 115(2-3): 208-14.