

# PRODUCTION AND CHARACTERIZATION OF SHEA BUTTER FOR USE AS BIO- LUBRICANT

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## ABSTRACT

*Shea butter was extracted from shea butter nuts and some of its properties characterized for possible use in the industrial and transport sectors as bio lubricant. The physico chemical analysis of the properties revealed the following results; Density at 25°C, 0.900 kg/m<sup>3</sup>, kinematic viscosities at 40 °C and 100 °C are 261.53 mm<sup>2</sup>/s and 38 mm<sup>2</sup>/s respectively, viscosity index is 191.39, pour point, 21 °C, flash point, 290 °C, neutralization number, 7.24 mg KOH/g while worked and unworked penetration numbers are 180mm and 317 mm respectively. The results obtained indicate that Shea butter can suitably be used as lube base oil for the production of lubricants.*

Keywords: Bio lubricant, Lubrication, Mineral oil, Shea butter, internal combustion engines

## 1 INTRODUCTION

The reliable and safe operation of an automobile at desired operating conditions requires effective lubrication of moving parts to allow them slide smoothly over each other. Reducing wear and friction is a key element to decrease energy losses, particularly in engines and drive trains. Mineral oils have been used as lubricants in IC engines for a long time. However, as products of the distillation of crude oil, mineral oils can only be used as long as crude oil is available. In addition, disposing of mineral oils leads to pollution in both aquatic and terrestrial ecosystems. Furthermore, the combustion of mineral oils as a lubricant has been proven to emit traces of metals, such as calcium, phosphorous, zinc, magnesium, and iron Nano particles [1]. They analyzed current and future prospects of mineral oils as lubricants in automobile engines and predicted bleak future prospects. The increasing oil prices, the depletion of the crude oil reserve in the world, and the demand to protect the environment against pollution caused by petrochemical based lubricating oils and their uncontrolled spillage have renewed interest in developing and using alternative lubricants. The development and formulation of bio based lubricants and products will checkmate these problems. A lubricant is a substance that reduces friction and wear by providing a protective film between two moving surfaces [1, 2]. Lubrication occurs when two surfaces are separated by a lubricant film. Lubricants are available in liquid, solid, and gaseous forms. A good lubricant exhibits the following characteristics: high viscosity index, high boiling point, thermal stability, low freezing point, corrosion prevention capability, and high resistance to oxidation. Lubricants exist in the three states of matter; gas, liquid and solid. Gaseous lubricants include air and neon. Liquid lubricants include: engine oil, gear oil and water based emulsion used as cutting fluids in metal working operations. Semi-solid/ solid lubricants are made by the dispersion of a thickening agent in a liquid lubricant.

The term “biolubricants” or “biolubs” include lubricating oils, lubricating greases, 2-stroke engine oils, hydraulic fluids and chain oils that are nontoxic to both humans and aquatic life and can biodegrade in relatively short time [3]. Biolubricant oils and fats are perceived as alternatives to mineral oils because they possess certain natural technical properties and they, unlike mineral oils are biodegradable. Compared with mineral oils, vegetable oil-based biolubricants generally exhibit high lubricity, high viscosity index (VI), high flash point, high viscosity and low evaporative losses. According to [1], biolubricants are made from plants such as palm, soybean, sunflower, rapeseed, and coconut. Biolubricants can also be made from synthetic esters and petroleum oils that satisfy established biodegradability and toxicity criteria. Biolubricants are generally considered as lubricants with high

biodegradability as well as low human and environmental toxicity. Both boundary and hydrodynamic lubrications can be obtained from bio lubricants because of their long fatty acid chains and the presence of polar groups in the structure of vegetable oil. Vegetable oils have excellent lubricity, which is far superior compared with that of mineral oils [4]. More importantly, vegetable oils are biodegradable, generally less toxic, renewable, can be obtained from oil-containing seeds which are available throughout the world and reduce dependency on imported petroleum oils. These desirable characteristics of vegetable oils and animal fats make them attractive as lubricants for chain saws, railroads and also for hydraulic fluids in power equipment, two- stroke engines, boat engines and so on [5].

Many researchers have reported using vegetable oil as engine fuel, but only a few have reported using vegetable oil-based lubricants for automotive applications. This work attempts to investigate the lubricating properties of Shea butter for use as bio lubricant. Shea nut butter is the fat content of Shea nut (*vitelaria paradoxa*) and belongs to the family of *sapotaceae* which grows naturally wild and uncultivated in most part of Africa [6, 7]. It is known locally as 'kadanya', 'emi', 'osisi' and 'chammal', among the Hausas, Yorubas, Igbos and Tivs, respectively [8]. According to [8], in Nigeria, Shea nut is obtained abundantly in Oyo State and most of the Northern States and contains 45-60% fat and 9% protein According to [9] Shea butter is used as a cooking fat, illuminant, medical ointment, hairdressing cream and as raw material in the manufacture of soap, candle, cosmetic products and also serves as a constituent of filling for chocolate creams.

## 2 MATERIALS AND METHODS

### 2.1 Materials Collection, Preparation and Shea butter extraction

The Shea nuts were collected in the bushes around Girei town in Girei local government area of Adamawa State, Nigeria. They were sun dried, cleaned by removal of unwanted materials such as stones and dirt and manually cracked using stones and woods to obtain clean kernels. The kernels obtained were roasted and ground into paste using pestle and mortar. This was followed by the extraction of oil from the kernel paste which involves the kneading of paste, boiling it in water, scooping off the oil and drying it by heating to remove all traces of moisture.

### 2.2 Determination of Density

20 ml of liquid Shea butter was measured in a pre- weighed measuring cylinder. The weight of the cylinder and Shea butter was measured. The weight of Shea butter was then obtained by subtracting the weight of cylinder from the weight of cylinder and Shea butter. The specific density of Shea butter was obtained using the equation [1] below

$$\text{Density of oil} = \frac{W_1 - W_2}{V_o} \quad [1]$$

Where,  $W_1$  = weight of measuring cylinder + oil,  $W_2$  = weight of empty measuring cylinder,  $V_o$  = volume of oil.

### 2.3 Determination of Kinematic Viscosity (Method: ASTM D 88).

Viscosity is the property of liquid by virtue of which it offers resistance to its own flow (the resistance to flow of liquid is known as viscosity). It is the most important single property of any lubricating oil, because it is the main determinant of the operating characteristics of the lubricant. If the viscosity of the oil is too low, a liquid oil film cannot be maintained between two moving/sliding surfaces. On the other hand, if the viscosity of the oil is too high, excessive friction will result.

To determine the viscosity of Shea butter, a viscometer containing the Shea butter sample was placed in a constant temperature bath fixed at 40°C. The time taken for certain amount of the Shea butter sample to travel a fixed distance in a capillary tube was noted using a stop watch. The time taken for an equal amount of standard fluid to travel the same fixed distance in the capillary tube was also noted. Equation [2] was then utilized in the calculation of the viscosity. The same process was repeated with temperature kept at 100 °C to calculate the kinematic viscosity at 100 °C. Viscosity can be evaluated using the relation below:

$$\frac{\mu \text{ of standard fluid}}{\mu \text{ of sample}} = \frac{\text{flow of standard fluid}}{\text{flow of sample}} \quad [2]$$

Where  $\mu$  is viscosity in mm<sup>2</sup>/s

#### 2.4 Determination of Viscosity Index

The rate at which the viscosity of lubricating oil changes with temperature is measured by an arbitrary scale, known as Viscosity Index (V.I). If the viscosity of lubricating oil falls rapidly as the temperature is raised, it has a low viscosity index. On the other hand, if the viscosity of lubricating oil is only slightly affected on raising the temperature, its viscosity index is high. Viscosity index was computed using equation [3] below.

$$V.I = \frac{\text{viscosity at } 40^{\circ}\text{C}}{\text{viscosity at } 100^{\circ}\text{C}} \times Q \quad [3]$$

Where  $Q$  is a constant = 29.1046

#### 2.5 Determination of Pour Point (Method: ASTM D 97)

The temperature at which oil or lubricant ceases to flow is called pour point. Previously heated Shea butter sample was cooled at a specified rate in a pour point refrigerator and examined at 3°C intervals for flow. The lowest temperature at which sample movement is observed was noted and recorded as the pour point

#### 2.6 Determination of Flash Point (Method: ASTM D 93)

50 cm<sup>3</sup> of Shea butter sample was taken into a closed-cup tester and heated slowly with continuous stirring. A flame was inserted into the oil cup at every 2°C temperature rise of the Shea butter sample. The cup was filled with fuel sample and heated with an external heater. The agitator ensures that the fuel temperature is uniform. A small open flame was maintained from an external supply of natural gas. Periodically, the stirrer was stopped and the flame pivoted down to an opening in the top of the cup to see if the fuel vapors will ignite. Flash point of the Shea butter was noted as the lowest temperature at which application of the test flame causes the fuel vapour to give flash of fire and then disappeared.

#### 2.7 Determination of Neutralization or Acidic Number (Method: ASTM D 664)

Acidic number (TAN) is a measure of the amount of acidic substance in the oil. It used as a measure of oil degradation in service. 0.5g of propane naphtha was added to 20g of Shea butter in a flat conical flask. A standard solution of potassium hydroxide (KOH) was dissolved in 1000 cm<sup>3</sup> isopropyl alcohol and 5g of barium hydroxide (BaOH) added. The solution was boiled on a hot plate and allowed to cool then charged into a burette for titration. The point at which the Shea butter changes color is the stopping point and the cm<sup>3</sup> of the standardized base solution used was noted. TAN was then determined using litmus paper test.

#### 2.8. Determination of Penetration Number or Consistency of Grease (Method: ASTM D 217)

The consistency of lubricating grease is defined as its resistance to deformation under an applied force. The sample was placed in a worker cup. The cone assembly of ASTM penetrometer was allowed to drop freely on the Shea butter sample. The intensity was read directly from the penetrometer dial gauge.

### 3 RESULTS AND DISCUSSION

#### 3.1 Results

Results of evaluated properties of Shea butter are compared to SAE standards in table 1 while table 2 shows comparison of the evaluated properties with ISO standard lubes.

Table 1: Comparison of some Shea butter properties with SAE grade lubricants [10]

Property	Shea butter	SAE 30	SAE 40	SAE 50
Density at 25°C kg/m <sup>3</sup>	0.900	0.899	0.900	0.905
Kinematic viscosity at 40 °C mm <sup>2</sup> /s	251.53	110	139	225
Kinematic viscosity at 100 °C mm <sup>2</sup> /s	38.25	12	14	19
Viscosity index	191.39	266.79	288.97	344.65
Flash point °C	290	246	246	246
Pour point °C	21	-13	-18	-9
Neutralization number (TBN) mg KOH/g	7.24	12.5	12.5	12.5

Table 2: Comparison of Shea butter properties with some lubricants

Property	Viscosity at 40°C	Viscosity at 100°C	Viscosity index	Pour point °C	Flash point °C	Reference
Shea	251.53	38.25	191.39	21	290	(This study)
Castor seed oil	45.3	9.21	191	-8	215	[11]
ISO VG 46	>41.4	>4.1	>90	-10	Report to customer	[11]
ISO VG 220	>12	>4.1	>50	-6	265	[11]
Mineral oil based lube	568	27.8	62	-4	Report to customer	[11]
Synthetic lube	9.03	2.70	148	-	204	[11]
Fossil oil based lube	6.30	2.28	207	-27	211	[11]
Canola oil based lube	40.5	7.8	204	-66	216	[11]
Jatropha oil based lube	42.37	9.37	183	-3	205	[11]

### 3.2 Discussion

The determined density of Shea butter at 25 °C (0.900 kg/m<sup>3</sup>) corresponds to the densities of SAE 40 and SAE 50 lubricants which are 0.900 kg/m<sup>3</sup> and 0.905 kg/m<sup>3</sup> respectively as reported by Wagner, (2001)[10] and shown on Table 1. This means therefore that Shea butter can be used as base oil for the production of either SAE40 or SAE50 lubricants if density is the criterion. As can be seen in Table 2, both kinetic viscosities at 40 °C and 100 °C of shea butter are 251.53 mm<sup>2</sup>/s<sup>2</sup> and 38.25 mm<sup>2</sup>/s<sup>2</sup>

respectively. The values obtained shows that Shea butter viscosity meet the ISO viscosity grade requirement and is consistent with results reported by [11]. The results are almost similar to the results (256.17 mm/s<sup>2</sup> and 22.78 mm/s<sup>2</sup>) obtained by [12] for crude castor oil. The viscosity of a lubricant must always be high enough to keep good oil film between the moving parts; otherwise friction will increase resulting in power loss and rapid wear on parts [13]. When viscosity is the criterion, Shea butter is therefore a good feedstock for lubricants. From the result, it can be seen that Shea butter has viscosity index of 191.39 which is almost the same with that of castor seed oil (191) and much higher than that of mineral lubricant's 62 as reported by [11]. The result is in agreement with the report of [4]. If a bio lubricant with high viscosity index is used, its velocity will change less when the temperature of the engine increases. Failure to use oil with the proper velocity index when temperature extremes are expected may result in poor lubrication and equipment failure [14]. High VI permits lesser wear and lubricant consumption during application. According [11], lubricants with higher VI (>130) find a wide variety of applications in the automobile industry. The implication of this result is that from the viscosity index consideration, Shea butter is a good feedstock for the production of bio lubricant. The result of the analysis in Table 1 shows that the flash point of Shea butter is 290 °C which is about the same with the result of 296°C for crude castor oil reported by [12] and higher than the 265°C for ISO VG 220 standards in table 2. The high flash point indicates that using Shea butter as lubricant will ensure greater safety in the event of a fire incidence or even during storage. The higher the flash point of a substance, the lower is its flammability. According to [13], a lubricant with low flash point will be suspected of contamination with volatile products and usually require special precautions for safe handling. The Pour point of Shea butter sample was found to be 21°C which is too high when compared to SAE standards as can be seen in table 1. It is also higher than ISO VG 46 and ISO VG 220 standards of -10°C and -6°C as reported by respectively as reported by Musa et al., (2015). It is also higher than the -12 °C for crude castor oil reported by [12]. This is unfavorable as pour point is an important property of lubricant base oils which determines their low temperature usability. The high pour point can be attributed to the fact that even at atmospheric temperature, Shea butter is semi solid and will easily solidify at lower temperatures. This anomaly however, can be corrected by the use of pour point depressants to lower it to an acceptable level. The low neutralization or acid value of Shea butter (7.25mgKOH/g) is a clear indication that when used as bio lubricant base stock, it will not fail in service due to acid reaction or contamination. Too high acidic value may indicate contamination or severely oxidized oil.

#### 4 CONCLUSION

Based on the results obtained, the following conclusions are drawn: Generally, the physico-chemical properties of the produced Shea butter sample fell within the ISO VG 46 ISO VG 220 and SAE specifications for bio lubricants. Due to its high viscosity, high flash point and high viscosity index Shea butter can be used in the production of SAE 50 grade of lubricants. In low temperature environments, Shea butter cannot be used as lubricant because of its high pour point.

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