UMYU Scientifica, Vol. 5 NO. 1, March 2026, Pp 101 – 109
https://doi.org/10.56919/usci.2651.009
ISSN: 2955 – 1145 (print); 2955 – 1153 (online)
A periodical of the Faculty of Natural and Applied Sciences, UMYU, Katsina

ORIGINAL RESEARCH ARTICLE

Comparative Study between ISO VG-46 and Biolubricants Synthesized from Neem (*Azadirachta indica*) and Calabash (*Lagenaria siceraria*) Seed Oils Using Calcium Oxide (CaO) Catalyst Obtained from Eggshells for Application as Hydraulic Fluids

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ABSTRACT
The research focused on the extraction of oil from Neem (*Azadirachta indica)* and Calabash (*Lagenaria siceraria)* seeds. The extracted oils were characterized to determine their physicochemical properties, which were assessed according to AOAC and ASTM methods. The percentage yields of Neem oil and Calabash oil were 34.50±0.25% and 31.00±0.20 %, respectively. The acid value of Neem and Calabash oils was 8.91±0.10 mg KOH/g and 3.23±0.15 mg KOH/g, respectively. Regarding percentage Free Fatty Acids (% FFA), Neem oil was determined to be 4.87±0.20 while Calabash oil had a value of 1.73±0.10. As for the saponification value, Neem oil had a value of 137.55±0.25 mg KOH/g, while calabash oil had a value of 238.84±0.30 mg KOH/g. The iodine values of neem and calabash oil were 68.00±0.20 and 66.20±0.15 g/100g, respectively. Also, the density for neem oil was determined to be 0.85±0.10 g/mL, while that of calabash oil was 0.90±0.10 g/mL. Furthermore, the extracted Neem and Calabash oils were used to synthesize biolubricants via esterification and transesterification processes using pentaerythritol and Calcium Oxide (CaO) obtained from eggshells, with yields of 60.80±0.15 % for the Neem biolubricant and 53.00±0.20 % for the Calabash biolubricant. The properties of the synthesized biolubricants were determined and compared with those of a mineral lubricant (ISO VG 46). Additionally, tribology studies showed that the COF for Neem and Calabash biolubricants is 0.041 and 0.054, respectively, at a 10N load. Compared with the COF of 0.086 for ISO VG 46 at 10N load, these biolubricants could provide better friction reduction than ISO VG 46; hence, they are suitable for possible application as hydraulic oil.

ARTICLE HISTORY
Received December 17, 2025
Accepted March 04, 2026
Published March 15, 2026

KEYWORDS
Neem, Calabash, Biolubricant, Pentaerythritol, transesterification, Eggshells, Coefficient of Friction (COF)

INTRODUCTION
At the global level, petroleum-based products are extensively used as lubricants. These products are non-renewable, and persistent use makes them toxic to the environment when improperly disposed of. With the growing demand for fuel, the depletion of world's reserves is imminent. As such, there is a need to find renewable and sustainable alternatives (Syahir *et al*., 2017).

Biolubricants are promising candidates for eco-friendly lubricants because of their excellent lubricity, biodegradability, viscosity-temperature characteristics and low volatility. Recently, there has been increased concern about enhancing the use of biodegradable vegetable oils in lubricants, mostly due to environmental, health, and safety issues arising from changes in economic and supply factors (Aji *et al*., 2015). From an emissions perspective, biolubricants have very low potential to emit pollutants containing sulphur compounds, which can damage the environment and the catalytic converters of automobiles (Dattrao *et al*., 2018).

Literature reports on the use of Neem and calabash seeds as biolubricants were presented elsewhere (Amit et al., 2015; Owuna *et al*., 2018). So far, the use of pentaerythritol in the transesterification reaction of Neem and Calabash oil extracts to their respective biolubricants are scarce, presented herein, includes a comparative study of the physicochemical properties of Calabash and Neem seed oils and the synthesis of biolubricants from these oils using pentaerythritol and a calcium oxide catalyst obtained from egg shells. The physicochemical properties of the synthesized biolubricants were analyzed and compared

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How to cite: Ado, O. E., Ibrahim, H., & Lawal, N. S. (2026). Comparative Study between ISO VG-46 and Biolubricants Synthesized from Neem (*Azadirachta indica*) and Calabash (*Lagenaria siceraria*) Seed Oils Using Calcium Oxide (CaO) Catalyst Obtained from Eggshells for Application as Hydraulic Fluids. *UMYU Scientifica*, 5(1), 101 – 109. https://doi.org/10.56919/usci.2651.009

with those of a commercial standard (ISO VG-46) for possible use as hydraulic fluids.

MATERIALS AND METHODS

Sample Collection

Calabash seeds were obtained from the Samaru Market, authenticated at the Herbarium, Department of Botany, Faculty of Life Sciences, Ahmadu Bello University, Zaria, and assigned the vouch number ABU014147. The seeds were de-hulled, dried, ground and sieved to obtain a homogenous powder. The powdered calabash seed weighed 500 g and was then preserved for oil extraction. Neem seeds were obtained from the ABU Zaria main campus, treated the same as calabash seeds, and assigned vouch number ABU090016; the weight of powdered neem seed was determined to be 950 g.

Materials and Reagents

Neem and Calabash oils (Extracted as stated below), Methanol, n-hexane, Pentaerythritol, Potassium hydroxide, Sodium hydroxide and Ethanol were all purchased from BDH and were all analytical grade. Calcium Oxide was obtained from egg shells via calcination in an oven.

Extraction of Oils

A Soxhlet extractor was employed for the extraction of oil from calabash and neem seeds using n-hexane as the extracting solvent in a 500 cm^3 round-bottom flask. 50 g of powdered calabash seed was placed in a thimble, while the n-hexane was gently heated. A reflux condenser was fitted (to cool the n-hexane), and the mixture was heated at 65 ^oC for 2 hours while the condensed hot solvent soaked the thimble.

Fig. 1: The extracted Neem (dark) and Calabash (orange) oils

The solvent siphoned into the flask when it reached the top of the siphon tube. The oil was separated from the solvent using a rotary evaporator. The same treatment as above was given to the neem seeds. The percentage yield of the oil was calculated using the equation below (Owuna *et al.*, 2018; Terefa *et al.*, 2018; Awasthi *et al.*, 2019). The procedure was repeated three times with a fresh seed sample, and the percentage yield was recorded.

$$\%\ yield = \frac{Weight\ of\ Oil\ (g)}{Weight\ of\ the\ sample}\ X\ 100$$

Characterization of the Extracted Oils

The physico-chemical properties of the extracted oils, such as Acid Value, Saponification Value, Percentage Free Fatty Acids (%FFA), Iodine Value, Density, and Specific gravity, were determined according to AOAC and ASTM methods, respectively.

Synthesis of Calcium Oxide Catalyst from Eggshells

Calcium Oxide catalyst was prepared from waste eggshells by the calcination method. Egg shells were collected from food vendors at Community Market A.B.U Zaria, then washed using distilled water and sun-dried. Furthermore, the egg shells were crushed and calcined in the furnace at 800 ^oC for 1 hour. After cooling, the resultant solid product was ground, sieved and kept in air-tight sample bottles. The sample bottles were kept in the desiccator to prevent air from contacting them. The catalyst was activated by impregnating a known quantity of the powdered sample with phosphoric acid (H_3PO_4). An impregnation ratio of 15 g of H_3PO_4 to 5 g of the calcined egg shells was used. The use of phosphoric acid in acid impregnation enhances the surface properties, catalytic activity, and stability of the catalyst. The phosphoric acid increases the surface area, thereby allowing for effective activation of the CaO catalyst (Erchamo *et al.*, 2021; Saleem, 2022).

The mixture was stirred for 30 minutes until a paste formed, then allowed to stand for 24 hours. The activated substrate was filtered using filter paper. The mixture was washed by gradually pouring distilled water over the filter paper containing the sample, which was placed over a conical flask. The pH of the filtrate was checked regularly with a pH meter until it was within 6–8. The activated substrate was then dried in an oven at 105 ^oC for 10 minutes (Olufemi *et al.*, 2020; Correira *et al.*, 2014). The equation of reaction is shown below:

$$CaCO_3(s) —\Delta\longrightarrow CaO(s) + CO_2(g)$$

Synthesis of biolubricants from Calabash and Neem Oils via Esterification and Transesterification

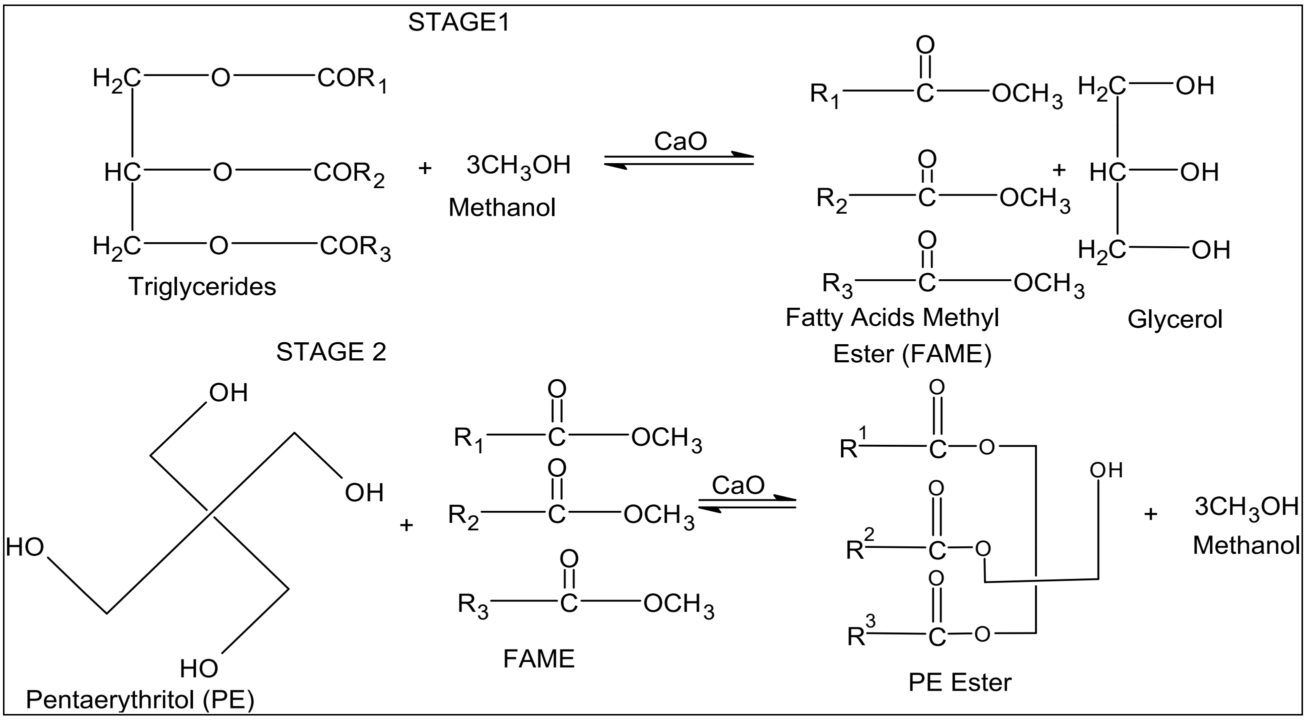
The vegetable oils extracted from Calabash and Neem seeds were each filtered to remove any solid precipitates, then dried by heating at 100 ^0C for 30 min to remove moisture. The experimental procedures reported below were carried out separately for Calabash and Neem oils. The esterification and transesterification reactions are shown in Scheme 1.

- *Esterification*

2.5g CaO (1% by wt of oil) was added to 400 mL of methanol and dissolved by vigorous stirring. The mixture was poured into 50 mL of the calabash oil. The reaction mixture was stirred for 90 min at 60 °C. The heater is then switched off. The reaction was quenched by adding ice, then allowed to settle and separate into phases. The top ester layer is poured into another beaker and washed with 400 mL of water three times. After some time, the water phase containing the remaining alcohol and catalyst settled, leaving a clear ester phase on top, which is separated and used for the next reaction (Dattrao *et al.,* 2018). Yields of Fatty Acid Methyl Esters (FAME) are 42.50±0.20 % (Neem) and 50.10±0.20 % (Calabash).

- *Transesterification*

12.5 g of Pentaerythritol was added to 50 mL of Calabash Seed Oil Methyl Ester in a three-neck round-bottom flask fitted with a thermometer. The mixture was heated on a magnetic stirrer to 150 °C with continuous stirring, then 0.5 g of calcium oxide (CaO) catalyst (1% by wt of methyl ester) was added. The vacuum pump was turned on to remove methanol from the reversible reaction. At the end of the reaction, the mixture was cooled, washed with water, dried with anhydrous sodium sulphate and filtered (Dattrao *et al.,* 2018; Orhevba *et al.,* 2016). Yields of biolubricants are 60.80±0.15 % (Neem) and 53.00±0.20 % (Calabash).



Scheme 1: Reaction pathway for the synthesis of the biolubricants

Physico-chemical Properties of Synthesized Biolubricants

The basic properties of biolubricants were analyzed using American Society for Testing and Materials (ASTM) methods. These properties include: Density, Viscosity, Cloud point, Pour point, Specific gravity, and Flash point. These properties were investigated and compared with those of a mineral lubricant (ISO VG 46) to assess the potential application of the synthesized biolubricants as hydraulic oil (Kamarudin *et al.,* 2020; Owuna *et al.,* 2018).

Density (ASTM D792)

An empty 2 mL syringe was placed on a weighing balance and recorded as W_1. The syringe was then filled with neem oil biolubricant and placed on the weighing balance again. The weight was recorded as W_2. The density was calculated as shown below:

$$Density = \frac{W2 - W1}{2\ mL}$$

Viscosity (ASTM D445)

A Brookfield viscometer was used to determine the viscosity values of neem and calabash oil biolubricants at 40 °C and 100 °C. Firstly, spindle size 3 was selected, and the neem biolubricant sample was transferred into a 100 mL beaker. The temperature of the biolubricant was raised to the desired value by heating on a mantle with a thermometer inserted into the beaker. The spindle was attached to the upper coupling and immersed in the sample to the midpoint of the indentation in the shaft. The viscometer was then turned on and allowed to run until a constant reading was attained; the reading was recorded as the absolute viscosity of the biolubricant in centipoise (cP). The values of absolute viscosity in centipoise (cP) at 40 °C and 100 °C were then converted to kinematic viscosity in centistoke (cSt) by dividing by the respective densities. The same treatment above was given to the calabash biolubricant (Rukke and Schuller, 2017).

Cloud point (ASTM D2500)

4 g of neem oil biolubricant sample was poured into a glass test tube until the level is marked with a line. The test tube was tightly capped with a cork, placed in a cooling bath, and monitored every 5 mins. The sample was chilled until it became clouded at the bottom of the test tube. The temperature at which this occurred was recorded as the

cloud point (Kamarudin *et al.,* 2020). The same procedure was carried out for calabash oil biolubricant.

Pour point (ASTM D97)

Pour point was measured using the same procedure as cloud point described above. However, further chilling of the biolubricant sample continued until the biolubricant sample ceased to flow. The sample was then removed and tilted horizontally for 5 seconds; the temperature at which it no longer showed movement was recorded as the pour point (Kamarudin *et al.,* 2020).

Specific Gravity (ASTM D941-55)

Specific Gravity is the ratio of the density of a biolubricant sample to the density of equal volume of distilled water. This is usually determined by using an instrument called hydrometer (Kamarudin *et al.,* 2020).

Flash point (ASTM D93)

1.0 g of neem oil biolubricant was weighed into a conical flask and heated, with the electrode of a thermocouple inserted into the flask. The heating continued in a fume cupboard until the oil was observed to have vaporized. A burning splint was taken close to the mouth of the conical flask. The temperature at which the oil vapour ignited was then recorded as the flash point. The same procedure was carried out for the calabash oil biolubricant to determine its flash point.

FTIR Analysis of Biolubricants

The biolubricants synthesized from Neem and Calabash seed oils were analyzed for functional groups using an FTIR instrument (Agilent Technologies) with a wave number range of 4000-650 cm-1 at the Multi-User Science Research Laboratory, Department of Chemistry, A. B. U. Zaria.

Reusability Test of the CaO Catalyst

The reusability of the CaO catalyst was evaluated over three consecutive reaction cycles under identical operating conditions. After each cycle, the catalyst was separated by filtration, washed with n-hexane and methanol to remove residual organic species, dried at 105 °C, and reactivated by calcination at 800 °C for 3 h. The recovered catalyst was reused without modification of reaction parameters. Catalyst performance was assessed based on ester yield and physicochemical properties of the biolubricant (Tavizón-Pozos *et al.,* 2025). The percentage FAME and biolubricant yield were calculated using the formula below:

$$\text{The \% FAME yield} = \frac{\rho(biodiesel) x\ Vol.(biodiesel)}{Mass\ (biodiesel)} X\ 100$$

$$\text{The \% Biolubricant yield} = \frac{\rho(biolub) x\ Vol.(biolub)}{Mass\ (biolub)} X\ 100$$

RESULTS AND DISCUSSION

Physico-chemical properties of Neem and Calabash Seed Oils

The oil yield of Neem seed was 34.50 %, while that of Calabash seed was 31.00 % (Table 1). The result agrees with the work of Abul Kalam et al. (2018), which indicated that the percentage yield of neem oil from seed kernels varies from 25–45 %. The acid value for neem oil was determined to be 8.91 mg KOH/g, while that of calabash oil was 3.23 mg KOH/g. Acid value is the amount of KOH (mg) required to neutralize the free fatty acids in 1 g of oil sample; it indicates the amount of free fatty acids present in an oil and is a good indicator of oil degradation caused by hydrolysis (Tesfaye and Tefera 2017). Low acid values are desirable for oils because they indicate good cleansing properties and stability, while high acid values indicate deterioration (Awasthi and Shikha 2019).

Table 1: Physico-chemical properties of Neem and Calabash oils

Parameter	Neem Seed Oil	Calabash Seed Oil
Colour	Dark-brown	Light orange
Percentage yield (%)	34.50 ± 0.25	31.00 ± 0.20
Acid value (mg KOH/g)	8.91 ± 0.10	3.23 ± 0.15
% Free Fatty Acids	4.87 ± 0.20	1.73 ± 0.10
Saponification value (mg KOH/g)	137.55 ± 0.25	238.84 ± 0.30
Iodine value (g/100 g)	68.00 ± 0.20	66.20 ± 0.15
Density (g/mL)	0.85 ± 0.10	0.90 ± 0.15
Specific gravity	0.85 ± 0.10	0.90 ± 0.15

The Percentage Free Fatty Acid (% FFA) of Neem oil was determined to be 4.87±0.20%, while that of Calabash oil was 1.73±0.20%. % FFA means the percentage by weight of specified fatty acids in oil. The determination of free fatty acid (FFA) content is important for evaluating the quality of the oil raw material and its degradation during storage. Low % FFA values are desirable because they indicate oil stability during storage, whereas high % FFA values indicate instability (Vicentini-Polette *et al.,* 2021).

The Saponification value of neem oil was determined to be 137.55±0.25 mg KOH/g, while that of Calabash oil was 238.84±0.30 mg KOH/g. Saponification value means the milligrams (mg) of KOH required to saponify 1 g of fat or oil. The saponification value is a measure of the molecular weight of fatty acids. The saponification value is used to detect oil adulteration. High saponification values indicate a greater proportion of medium-chain fatty acids in the oil and better usability (Ivanova *et al.,* 2022).

In terms of density, Neem and Calabash oils were 0.85±0.10 g/mL and 0.90±0.15 g/mL, respectively. Also, the Iodine values of Neem and Calabash oils are 68.00±0.20 and 66.20±0.15, respectively; Iodine value is a measure of the unsaturation of fats and oils and is expressed in terms of the number of grams of Iodine absorbed per 100 g of oil sample. The iodine values of these oils suggest a moderate level of unsaturation.

Physical properties of synthesized biolubricants

In Table 2, the densities of Neem and Calabash biolubricants are 0.87±0.20 g/mL and 0.93±0.15 g/mL, respectively, while that of ISO VG 46 was 0.85 g/mL, which is similar to the Neem biolubricant synthesized. Compared to the density values obtained from the extracted vegetable oils, there is an increase of 0.2-0.4 g/mL. The Kinematic Viscosities of Neem biolubricant at 40 °C and 100 °C were determined to be 45.80±0.15 cSt and 7.80±0.10 cSt, while those of Calabash biolubricant were 44.60±0.10 cSt and 7.58±0.10 cSt, respectively. These values are within the range of the Kinematic Viscosity of ISO VG 46 at 40 ⁰C and 100 ⁰C, which are >41.4 and >4.10, respectively.

Table 2: Physical properties of synthesized biolubricants compared to ISO VG 46

Parameter	Neem	Calabash	ISO VG 46
Yield (%)	60.80 ± 0.15	53.00 ± 0.20	–
Density (g/mL)	0.87 ± 0.20	0.93 ± 0.15	0.85
Kinematic viscosity at 40 °C (cSt)	45.80 ± 0.15	44.60 ± 0.10	> 41.4
Kinematic viscosity at 100 °C (cSt)	7.80 ± 0.10	7.58 ± 0.10	> 4.10
Cloud point (°C)	20.00 ± 0.20	4.00 ± 0.10	–
Pour point (°C)	4.00 ± 0.10	–6.00 ± 0.10	< –10.00
Viscosity index	130 ± 0.15	128 ± 0.10	108
Flash point (°C)	183 ± 0.20	179 ± 0.15	227

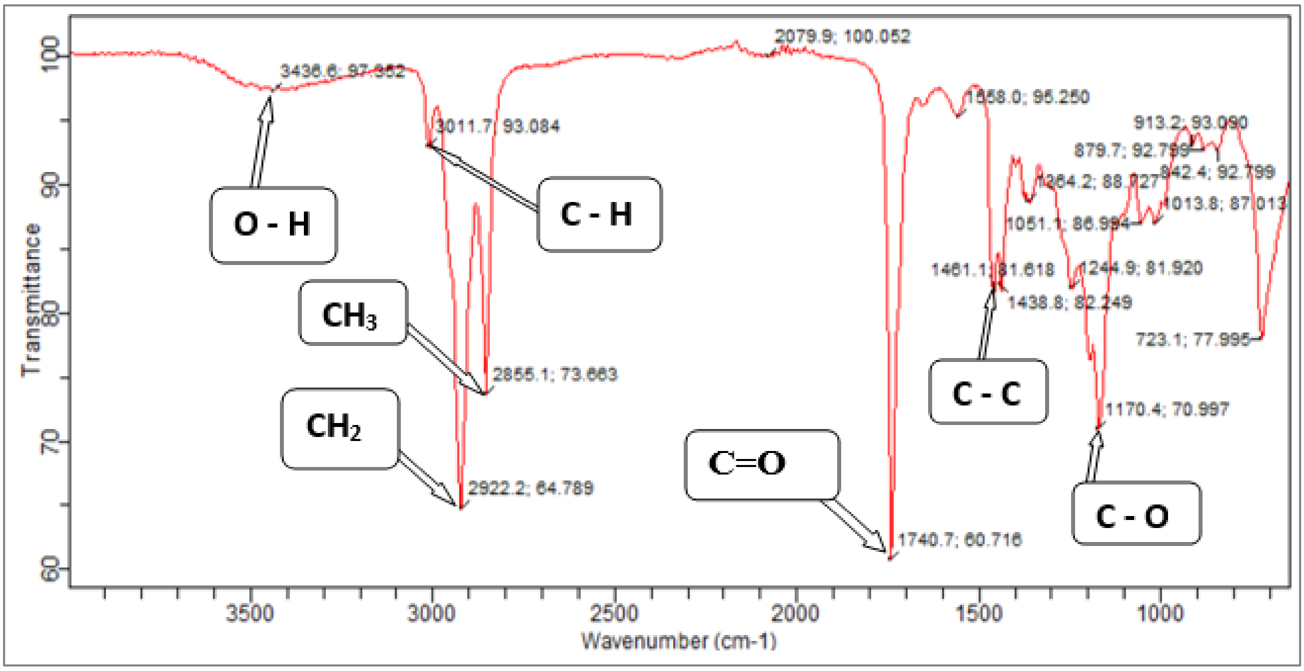


Fig. 3: FTIR Spectrum of Calabash biolubricant

The Cloud point values of Neem and Calabash biolubricants were determined to be 20±0.20 °C and 4.0±0.10 °C while that of ISO VG 46 was not available from literature specifications. The Pour point values of Neem and Calabash biolubricants were determined to be 4.0±0.10 °C and –6.0±0.10 °C, respectively, while that of ISO VG 46 was less than –10. This implies that ISO VG 46 has an edge over synthesized biolubricants for cold-temperature applications.

Furthermore, the Viscosity Indices of Neem and Calabash biolubricants vis-à-vis ISO VG 46 are 130±0.15 and 128±0.10, respectively. This shows that the synthesised biolubricants are more suitable for high-temperature applications. Lastly, the Flash point values of Neem and Calabash biolubricants were determined to be 183±0.20 °C and 179±0.15 °C, respectively, while ISO VG 46 was 227 °C. Generally, a high flash point is desirable for lubricants because it is a safety index for their storage and handling. This means ISO VG 46 will be easy to handle during storage.

FT-IR Spectra of Biolubricants

The FTIR spectrum of Calabash biolubricant is provided in Figure 3; a broad peak at 3436 cm-1 was observed, confirming the presence of a hydroxyl (O-H) stretch. The absorption wave peak of 3011 cm^{-1} indicated a strong C–H bond. Furthermore, a prominent peak was observed at 2922 cm^{-1} indicating the presence of methylene (CH_2) group while another peak occurred at 2855 cm^{-1} due to C–H which confirms the presence of a methyl (CH_3) group in the structure. The carbonyl bond (C=O) present in the ester functional group (R-C=O-O-R') was observed to occur at 1740 cm^{-1}. The absorption wave peaks at 1461 cm^{-1}, indicating the presence of carbon chain bonds between C–C, while the absorption wave peaks at 1170 cm^{-1}, indicating the presence of C–O bonds.

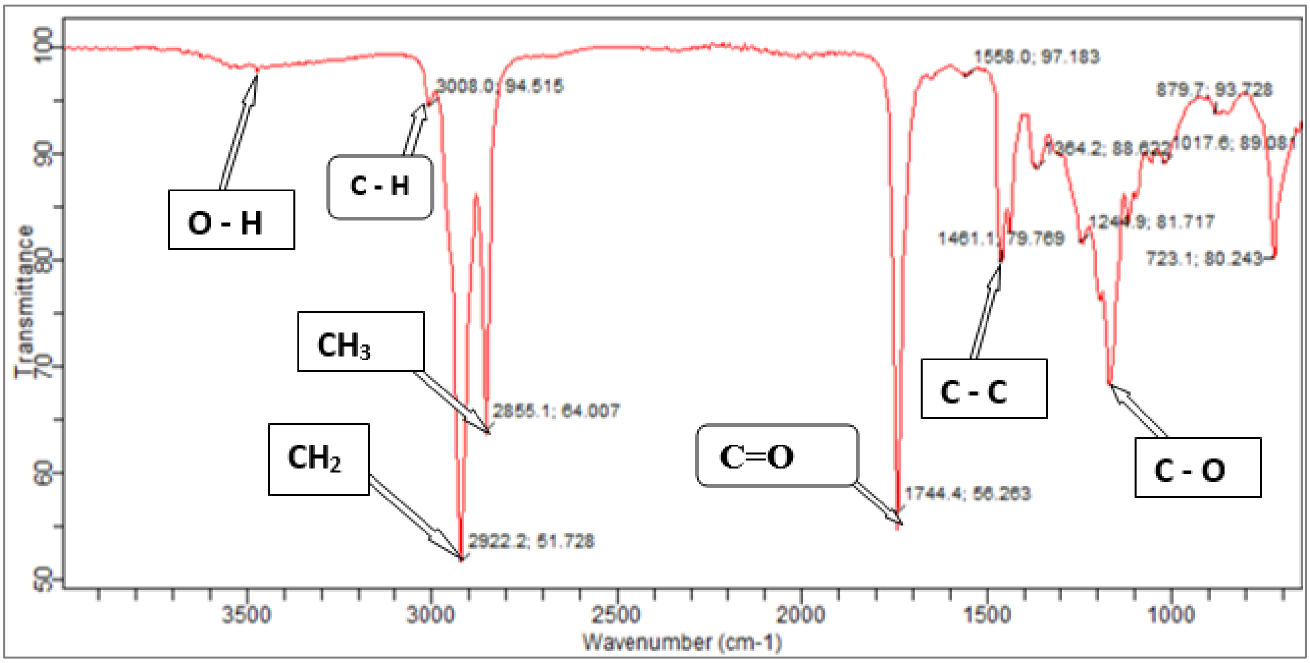


Fig. 4: FTIR Spectrum of Neem biolubricant

Table 3: GC-MS profile of Neem biolubricant

S/N	F.A.M.E	Molecular Formula	% Composition
1	Methyl tridecanoate	$C_{14}H_{28}O_2$	40.36
2	Linolelaidic methyl ester	$C_{19}H_{34}O_2$	21.85
3	12-Methyl-2,13-octadecadien-1-ol	$C_{19}H_{36}O$	15.12
4	Decanoic acid methyl ester	$C_{11}H_{22}O_2$	7.92
5	14-Methylpentadecanoate	$C_{17}H_{34}O_2$	3.60
6	15-Methylhexadecanoate	$C_{18}H_{36}O_2$	1.97
7	11,14-Eicosadienoic acid methyl ester	$C_{21}H_{38}O_2$	1.53
8	2-Methylbutyl ester	$C_8H_{16}O_2$	1.48

Table 4: GCMS profile of Calabash biolubricant

S/N	F.A.M.E	Molecular Formula	% Composition
1	10-Pentadecen-1-ol	$C_{15}H_{30}O$	34.54
2	9,12-Octadecadienoic acid methyl ester	$C_{19}H_{34}O_2$	17.96
3	15-Tetracosenoic acid methyl ester	$C_{25}H_{48}O_2$	7.87
4	Hexadecanoic acid methyl ester	$C_{17}H_{34}O_2$	7.60
5	Tridecanoic acid methyl ester	$C_{16}H_{30}O_2$	5.36
6	5,17-Octadecadien-1-ol	$C_{20}H_{36}O_2$	5.31
7	13,16-Octadecadienoic acid methyl ester	$C_{19}H_{34}O_2$	5.15
8	Methyl 10-oxohexadecanoate	$C_{17}H_{32}O_3$	4.95

Table 5: The percentage FAME, Neem and Calabash biolubricant product yield after three cycles.

Neem			Calabash		
Run/Cycle	FAME Yield (%)	Biolubricant yield (%)	Run/Cycle	FAME Yield (%)	Biolubricant yield (%)
1st	42.50	60.80	1st	50.10	53.00
2nd	37.40	52.25	2nd	42.20	47.25
3rd	30.80	44.80	3rd	33.60	39.40

In Figure 4, an absorption band with a broad peak at 3436 cm-1 is observed, indicating the presence of a hydroxyl (O–H) bond. Another absorption wave peak of 3008 cm^{-1} indicated a strong C-H bond.

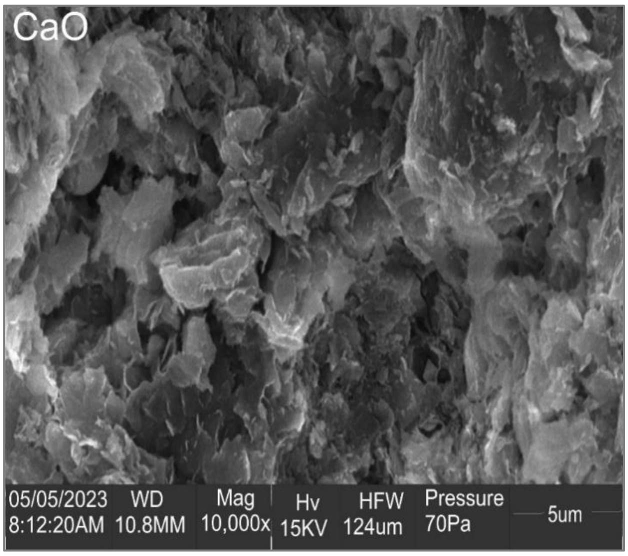


Fig. 5: SEM Micrograph of synthesized CaO catalyst

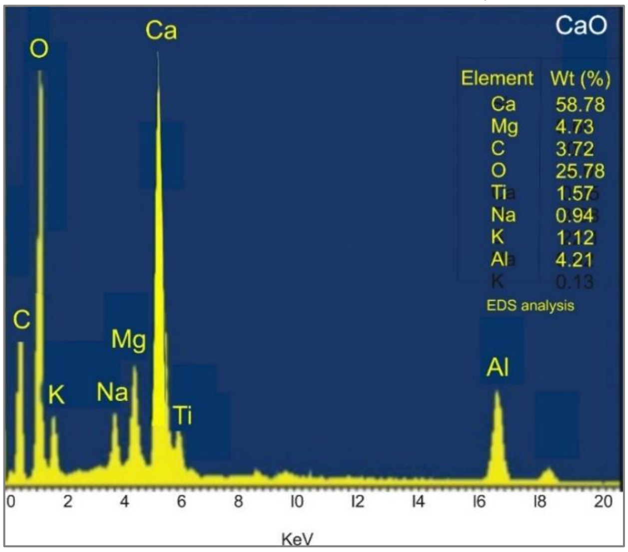


Fig. 6: EDS spectrum of synthesized CaO catalyst

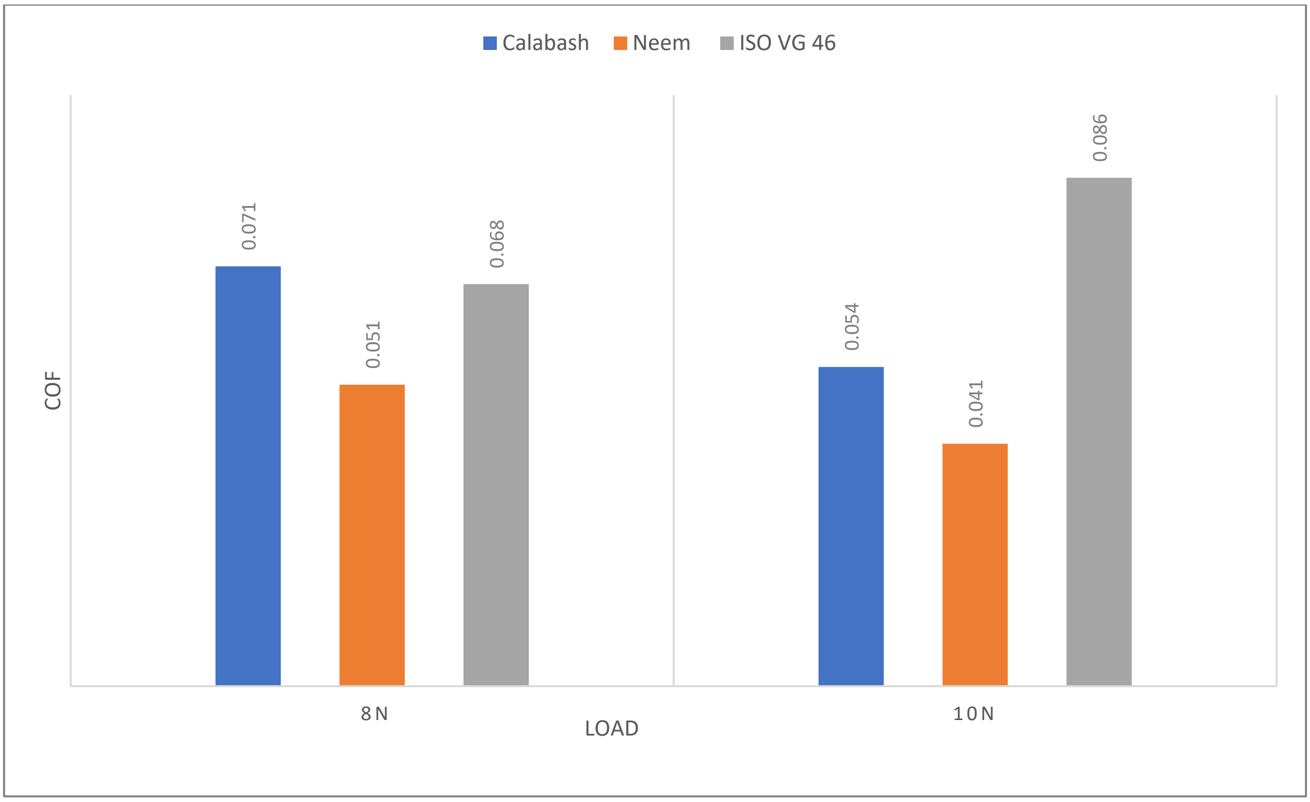


Fig. 7: Tribology test for ISO-VG 46, Neem and Calabash biolubricants at 8 N and 10 N loads

Also, a prominent peak at 2922 cm^{-1} indicated the presence of a methylene (CH_2) group; another peak at 2855 cm^{-1} was due to C–H stretching, confirming the presence of a methyl (CH_3) group in the structure. The carbonyl group (C = O) present in the ester functional group (R-C=O-O-R') was observed to occur with a prominent peak at 1744 cm^{-1}. The absorption wave peaks at 1465 cm^{1} indicated the presence of carbon chain (C-C), while the absorption wave peaks at 1115–1174 cm^{-1} indicated the presence of C-O bonds.

GC-MS profile of the biolubricants

The GCMS profile of the neem and calabash biolubricants produced are provided in Table 3 and 4, respectively. Both the calabash and neem biolubricants contain various ester derivatives. A further analysis of the chromatograms of the synthesised biolubricant showed the presence of additional organic byproducts of the reaction (see SI).

SEM and EDX Analysis of CaO obtained from eggshells

In order to investigate the morphology and structure of the synthesized CaO catalyst derived from egg shells, Scanning Electron Microscopy (SEM) analysis was conducted. The SEM micrograph shown in Figure 5 shows that the synthesized CaO catalyst consists of grains with irregular shape. The SEM image also shows the spaces between particle sizes, suggesting that the particles are porous. The presence of pores in the CaO gives efficient catalytic activity in biolubricant production.

Lastly, Figure 6 above is the Energy-Dispersive Spectroscopy (EDS) chromatogram, which shows the elemental composition of the synthesised CaO catalyst. The EDS chromatogram clearly indicates that CaO was formed at a high concentration. The percentage atomic compositions were obtained as 58.78, 25.78, 4.73, 4.21, 3.72, 1.57, 1.12 and 0.94 % for calcium (Ca), oxygen (O), magnesium (Mg), aluminum (Al), carbon (C), titanium (Ti), potassium (K) and sodium (Na), respectively. The results confirm that indeed CaO was produced.

Catalyst Reusability test

To test the reusability of the CaO catalyst obtained from eggshells, three synthetic cycles were conducted, and the results are presented in Table 5. Based on the data obtained, there is a decrease in catalytic activity (biolubricant yield) during the three consecutive uses. This could be attributed to the leaching of calcium from active sites into the methanol phase and to the poisoning of catalyst active sites by the reaction medium, which reduced the contact area between base sites and reactants (Nabilah *et al.*, 2021).

Tribology Analysis

The tribological performance of the ISO VG-46, Neem and Calabash biolubricants was investigated using a pin-on-disc tribometer (Anton Paar Model) shown in Figure 7. It can be observed that for the 8N load, the Coefficient of Friction (COF) for mineral lubricant (ISO VG-46) is 0.068. However, the Neem biolubricant showed a lower COF (0.051), while the Calabash biolubricant had a higher COF (0.071). The high COF of the Calabash biolubricant could be attributed to insufficient lubrication between the contacting metal surfaces, compared to ISO VG-46. For the 10 N load, the mineral lubricant (ISO VG-46) had a COF of 0.086. The COFs for Neem and Calabash biolubricants are 0.041 and 0.054, respectively, which means that at a 10N load, these biolubricants could provide better friction reduction than ISO VG-46.

CONCLUSION

The oils extracted from Neem and Calabash seeds showed good potential as base stock for biolubricant production. Neem and Calabash seeds yielded good oil percentages of 34.50% and 31.00%, respectively; the low Acid and % FFA values of the oils confirmed the stability and quality of the oil raw material. Biolubricants were synthesized from Neem and Calabash seed oils via esterification and transesterification processes, using CaO a catalyst obtained from eggshells. The major lubricating properties of Neem and Calabash biolubricants, compared to ISO VG 46, showed good agreement. The tribology study also showed that the biolubricants reduced the Coefficient of Friction (COF) between contacting surfaces. Hence, the synthesised biolubricants can preferably serve as alternatives to mineral-based lubricants in hydraulic applications. Moreover, the use of a CaO catalyst derived from eggshells, if scaled up, could greatly contribute to the recycling of waste materials in the environment into wealth.

ACKNOWLEDGMENTS

The authors express profound gratitude to the Federal Scholarship Board National Award (FSB–NA) for the disbursement of scholarship funds which contributed in no small measure to the research process.

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