

Performance Evaluation of Greases Produced from Wild Melon and Calabash Seeds

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ABSTRACT

In this study titled ‘Performance Evaluation of Greases Produced from Wild Melon and Calabash Seeds’ oil seeds from wild melon and calabash were investigated as base oils for the production of greases. The oil seeds were oven dried to moisture contents of 12.5 % and 11.1 % for calabash seeds and wild melon seeds respectively. The oils were extracted using solvent method. The percentage oil yields were 56.3 and 55.2 % for wild melon and calabash seeds respectively. Chemo-physical properties like flash point, free-fatty acid, viscosity index, and pour point of the oils proved that they are all suitable for the production of greases. The aim of this work was to produce greases from renewable raw materials that are environmental friendly and to improve upstream agricultural activities and provision of employment. The greases were prepared using Nailen and Yeong method. The greases produced were evaluated. Analysis of the produced greases showed that there was a gradual drop in viscosity with increase in temperature. It is recommended that greases produced using natural oil seeds like wild melon and calabash seeds be used as alternative to petroleum base grease. This is because the base oils are from renewable source, are less volatile and have high free fatty acid content.

Keywords: Evaluation of greases, grease lubricant, Melon and Calabash seeds.

INTRODUCTION

Lubrication is the process, or technique employed to reduce wear 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 to help carry the load (pressure generated) between the opposing surfaces. Adequate lubrication allows smooth continuous operation of equipment, with only mild wear, and without excessive stresses or seizures at bearings [1].

Wear leads to surface damage that involves a progressive loss of material and affects the lifetime of several mechanical elements such as gears and rolling element bearings [2]. Rolling contact wear (RCW) is a particular type of wear that results from the repeated mechanical stressing of the surface of a loaded body rolling against another [3]. To improve RCW life, lubrication is often employed. A lubricant film that aims to keep them sufficiently apart to prevent asperity contact separates the contacting surfaces. Among the most commonly used lubricants are greases, which provide low friction, are easily confined and have a long lubricating time at a low cost.

Burning generates both airborne pollutants and ash rich in toxic materials, mainly heavy metal compounds. Thus lubricant burning takes place in specialized facilities that have incorporated special scrubbers to remove airborne pollutants and have access to landfill sites with permits to handle the toxic ash.

Unfortunately, most lubricants that end up directly in the environment are due to general public discharging. Lubricants contain 90% base oil (most often petroleum fraction). Lubricants are essential and ease movements. When lubrication breaks down, metal or other components can rub destructively over each other, causing damage, heat and failure [4].

Petroleum-containing industrial wastes and petroleum products lost during processes (losses) are quantitatively and qualitatively basic environmental pollutants —of water, soil, and air. Some petroleum wastes from production and use of lubricants (greases, motor and industrial oils, etc.) are collected and regenerated. Wastes, which are not regenerated due to their physiochemical properties, are dangerous environmental pollutants [5]. When wastes (used oil or grease) are released into the soil, they are expected to quickly evaporate, or readily biodegrade or leach into the underground water; but when released into the air, the materials may be moderately degraded by photosynthesis or be removed from the atmosphere by wet disposition.

It is estimated that 40% of all lubricants are released into the environment. Unused lubricating grease is disposed of in accordance with all Federal, State and Local environmental regulations. In some cases, used oil recyclers will accept used grease. Some municipalities or industries hold household chemical disposal drives at which grease may be accepted. Depending on the service the grease has been in and contaminants to which it may have been exposed, used grease may be contaminated and considered to be hazardous waste and may require special handling for disposal. Used grease should not be re-used [6].

Disposal of used lubricants includes recycling, burning, landfill and discharge into water. There are typically strict regulations in most countries regarding disposal in landfill and discharge into water as even small amount of water. Most regulations permit a threshold level of lubricant that may be present in waste streams and companies spend hundreds of millions of dollars annually in treating their wastewaters to get acceptable levels. Burning the lubricant as fuel, typically to generate electricity is also governed by regulations mainly on account of the relatively high level of additives present. Burning generates both airborne pollutants and ash rich in toxic materials, mainly heavy metal compounds. Thus lubricant burning takes place in specialized facilities that have incorporated special scrubbers to remove airborne pollutants and have access to landfill sites with permits to handle the toxic ash. Unfortunately, most lubricants that end up directly in the environment are due to general public discharging onto the ground, into drains and directly into landfills as trash. Other direct contamination sources include runoff from roadways, accidental spillages, natural or man-made disasters and pipeline leakages. Improvement in filtration technologies and processes has now made recycling a viable option (with rising price of base stock and crude oil). Typically various filtration systems remove particulates, additives and oxidation products and recover the base oil. The oil may get refined during the process. This base oil is then treated much the same as virgin base oil however there is considerable reluctance to use recycled oils as they are generally considered inferior. Base stock fractionally vacuum distilled from used lubricants has superior properties to all natural oils, but cost effectiveness depends on many factors. Used lubricant may also be used as refinery feedstock to become part of crude oil. Again there is considerable reluctance to this use as the additives, soot and wear metals will seriously poison/deactivate the critical catalysts in the process. Cost prohibits carrying out both filtration (soot, additives removal) and re-refining (distilling, isomerization, hydrocrack, etc.) however the primary hindrance to recycling still remains the collection of fluids as refineries need continuous supply in amounts measured in cisterns, rail tanks. Occasionally, unused lubricants require disposal. The best course of action in such situations is to return them to the manufacturer where they can be processed as part of fresh batches [7].

Lubricants both fresh and used can cause considerable damage to the environment mainly due to their high potential of serious water pollution. Further, the additives typically contained in lubricants can be toxic to flora and fauna. In used fluids the oxidation products can be toxic as well. Lubricants persistence in the

environment largely depend upon the base fluid, however if very toxic additives are used they may negatively affect the persistence. Lanolin lubricants are non-toxic making them the environmental alternative, which is safe for both users and the environment [8].

Grease lubricant consists of oil and/or other fluid lubricant that is mixed with a thickener, a soap, to form a solid. Soap is a metallic salt of fatty acid, which forms an emulsion with oil. Greases are used where a mechanism can only be lubricated infrequently and where a lubricating oil would not stay in position. They also act as valuable sealants to prevent ingress of water and dust [9].

According to [10] the current trend in the production of grease is the use of base oil from petroleum source. Petroleum base stock for grease production is often scarce or expensive, not renewable and highly volatile. There is increased cost of exploitation and processing of mineral based lubricating oils, stringent environment regulation and dwindling reserves of petroleum crude. Petroleum (mineral) base grease is not biodegradable and causes upstream and downstream environmental pollution. It is toxic and can harm aquatic organisms. Free fatty acids (FFA) that forms metallic soaps with metal surfaces during lubrication of metals under boundary lubrication condition often encountered in metal work and to a large extent, in gear transmission system is very low with petroleum oils [11].

These actually have caused renewed and more intensive search for alternative, biodegradable and environmental friendly grease for engineering applications from short rotation plantation oil seeds that are regenerative and a veritable source of renewable oil seeds. Hence, this research works.

[12] defined oil seeds as varieties of lipids rich seeds, fruits, cereals, and nuts that are used in vegetable oils and fats for cooking, soap making, food manufacture, lubrication, fuels, paints and varnishes, and cosmetics among others. These oil seeds are products of many plants and each contains at least traces of lipids which are esters of fatty acid and glycerol.

Wild melon (*Citrus vulgare*) is a short-rotation plantation crop widely cultivated in the southern and middle belt regions of Nigeria. It is an important crop popularly known in Nigeria as 'egusi' by most ethnic groups. The place of origin is not known with certainty, but the center of origin and distributions is believed to be Asia. The composition of melon seeds, their nutritional chemical and biological characteristics is well established [13].

The oil from wild melon requires varying degrees of purification, depending on the extraction process, type of pigments present and utilization [14]. In their study of the rheological behaviour of wild melon oil lubricant blended with transmission oil it was concluded that the seeds of wild melon contain 52- 57% oil and 34% protein. The oil is yellowish in colour with a pleasant odour.

The calabash or Bottle gourd is a vine grown for its fruit, which can either be harvested young and used as a vegetable or harvested mature, dried, and used as a bottle, utensil, or pipe. Calabash seeds contain about 45% oil.

This study is restricted to the performance evaluation comprising chemo physical properties analyses and Rheological behaviour of greases. Seeds of interest included wild melon seeds and calabash seeds. Oils extracted from the seeds of interest above are the base oils for the grease production.

MATERIALS AND METHODS

Materials

The following oil seeds were used for this work; Calabash and Wild Melon. These seeds were procured

from open markets in Nasarawa and Benue states of Nigeria respectively. The oils were extracted using solvent method. These oil samples were blended. Each oil blend was used to produce grease.

Methods

Extraction and blending of oils

The seeds were broken and the oil seeds were collected. These oil seeds were dried properly, weighed, and cleaned to remove sand, dust, and other contaminants. The calabash seed oils and wild melon seed oils have similar extraction processes. The processed oil seeds were ground with a grinding machine. The finely ground grain were put into a clean new white cloth and tightened. The tightened cloth was put into a strong bucket. n – Hexane (a chemical/reactor) was poured on the tightened cloth until the cloth was submerged. The bucket was properly covered and left there for 24 hours. After 24hrs it was opened and kept under sun for 4 hours to enable n – Hexane to escape (evaporate). The extracted oil was then collected. The residue (chaff) was then weighted. The calabash oil and the wild melon oil were blended in equal ratio.

Characterization of the oil samples

The sample oils for this work were Calabash oil and wild melon oil and their blends. The characterisation was done using the following parameters with which base oil are identified as recommended by National Lubricating Grease Institute (NLGI):

Determination of flash point

10 ml of the sample was poured into a copper cup, a thermometer was secured to it and the sample was heated over a kerosene stove. A flame was passed over the surface of the sample at 5^oC intervals and its temperature observed. The temperature at which the vapour ignited with an easily detected flash was noted and recorded as the flash point.

Determination of fire points

10ml of the sample was poured into a copper cup, a thermometer was secured to it and the sample was heated over a kerosene stove. A flame was passed over the surface of the sample at 5^oC intervals and its temperature observed. The temperature at which the flame was sustained for five seconds was recorded as fire point.

Determination of cloud point

The cloud was determined in accordance with ASTM D-2500. 25 ml of each sample was poured into a measuring cylinder with a thermometer inserted into it and placed inside a refrigerator to cool and observed at intervals of 2 minutes. The temperature of first crystallization when the thermometer in the samples was no longer visible was observed and recorded as the cloud point of the sample.

Determination of pour point

The pour point of the samples was determined in accordance with ASTM D-97. 25 ml of each sample was weighed into a measuring cylinder of 25ml capacity and cooled in a refrigerator with a thermometer secured in place. The sample was observed at intervals of 2 minutes. The temperature at which wax became visible or at which the sample gelled was recorded as the pour point of the sample.

Determination of viscosity index

The value of viscosity index of the oil samples was determined by reading it off from a table specially constructed for the purpose as contained in viscosity index table for Celsius temperature given in ASTM data series. The value of the kinematic viscosity of the oil sample at 100⁰C was located in the table and traced down to the value of the kinematic viscosity of the same oil at 40⁰C and the value at the point of intersection represents the viscosity index of the oil sample.

Manufacture of Greases

The greases for this work were prepared according to [15] method using the following three steps.

- **Soap preparation (saponification process)**

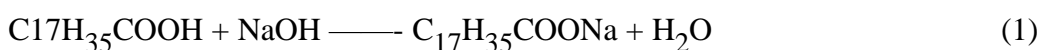
Stearic acid (C₁₇H₃₅ – COOH) was heated in an iron pot with aqueous sodium hydroxide at 110⁰C until the fat dissolved. The mixture was stirred and heated to form soap. The aqueous sodium hydroxide was a solution of 1 cup of caustic soda (sodium hydroxide) and 4 cups of water. The mixture was stirred vigorously at intervals for 24 hours until it became fermented chemical (aqueous sodium hydroxide).

- **Dehydration and condition of soap**

The reaction mixture (soap) was further heated to 200⁰C for 35 to 40 minutes to dehydrate the soap.

- **Incorporation of base oil and additive**

The soap which is the thickener was cooled to 180⁰C and held at this temperature while the base oil was added. That formed the grease. The grease was further cooled to 120⁰C with stirring and finally left to cool to room temperature after which the additive was added to the cooled grease.



Stearic acid

sodium stearate

Analysis of grease samples

The following tests were carried out to analysis the grease samples:

Determination of dropping point of lubricating grease over wide temperature range.

This test was carried out in accordance with ASTM D – 2265 using aluminium block oven equipment.

The dropping point temperature was calculated using equation 2

$$Dpt = T_1 + (T_2 - Dpt)/3 \quad (2)$$

Where; Dpt is the dropping point of grease sample, T₁ is the thermometer reading when the first drop reaches the bottom of the test tube, and T₂ is the block temperature when the drop falls.

Determination of apparent viscosity of grease samples

The apparent viscosity of the grease samples was determined according to the ASTM method D-1092. The

apparent viscosity was calculated as;

$$V_{ab} = Ct_{ab} \quad (3)$$

Where; V_{ab} is the determined apparent viscosity value for V_a and V_b respectively (mm^2/s), C is the calibrated constant of the viscometer (mm^2/s), T_{ab} is the measured flow time t_a and t_b respectively. Then, the apparent viscosity result, V is the average of V_a and V_b .

Viscosity temperature coefficient (VTC)

The apparent viscosity coefficient was evaluated using equation 4

$$\text{VTC} = \frac{(\text{Apparent viscosity at } 400\text{C} - \text{Apparent viscosity at } 1000\text{C})}{(\text{Apparent viscosity at } 400\text{C})} \quad (4)$$

Determination of the consistency (penetration) of the grease samples. This test was carried out using a penetrometer in accordance with ASTM D – 217.

Statistical Analysis

Multiple regression modeling

Regression model was formulated for predicting viscosity index, the formulated equation was;

$$VI = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + E \quad (5)$$

Where VI is the viscosity index, $X_1 - X_9$ are the inputs (predictors); and E and ϵ are the errors between the predicted and experimental viscosity index.

x_1 is the thickener used;

x_2 is additives used,

x_3 is the Free-fatty acid,

x_4 is the density

x_5 is the cloud point

X_6 is the viscosity temperature coefficient

X_7 is mechanical stability

X_8 is the kinematic viscosity at 100°C

X_9 is the penetration

A programme for multiple regressions using the **reglin** function as shown in Plate 1 is written and executed in the SCILAB environment to evaluate the coefficients $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8$ and β_9 . These coefficients were then substituted in equations (5) to give the formula for the prediction of viscosity index.

```
x1=[70 50 65 70 100 80 120 200 140 180]
x2=[12 18 20 20 25 40 30 26 30 40]
x3=[3.4 3.4 2.6 2.82 3.5 3.7 3.8 3.4 4.0 4.2]
x4=[0.0879 0.909 0.875 0.925 0.885 0.881 0.890 0.890 0.910 0.900]
x5=[13 8 8 8 9 9 9 11 11 12]
x6=[0.2381 0.2400 0.2400 0.2418 0.2265 0.2290 0.2274 0.2288 0.227 0.228]
x7=[35 40 30 45 40 41 32 45 39 40]
x8=[21 71 65 50 111 109 109 108 108 108]
x9=[179 270 315 235 230 325 185 360 360 190]
y= [70 236 216 165 370 362 362 358 356 358]
X=[x1; x2; x3; x4; x5; x6; x7; x8; x9]; // create matrix x from the nine rows
[a, a0, sigma]=reglin (X,y); // perform a multiple regression analysis of y as a function of x1, x2, x3, x4, x5,
x6, x7, x8 and x9
ypred = a0 + a(1)*x1 + a(2)*x2 + a(3)*x3 + a(4)*x4 + a(5)*x5 + a(6)*x6 + a(7)*x7 + a(8)*x8 + a(9)*x9;
// fitted data
filename = myreglindir + basename(myfile) + "-plot.png"; // create filename from basename of file
xs2png(wn, filename); // save graphic in PNG format
result = ["a0" "a(1)" "a(2)" "a(3)" "a(4)" "a(5)" "a(6)" "a(7)" "a(8)" "a(9)"]; // first row of data
result(2,:) = string([a0 a]); // convert coefficients to string for export
result(:, $) = result(:, $) + "\\ hline"; // add end of line commands for LaTeX table
filename = myeeglindir + basename(myfile) + "text"; // filename for saving results
csv Write(result, filename, "&"); // use "&" to separate the columns
```

Plate 1: Programme code for the prediction of Viscosity index.

RESULTS AND DISCUSSION

Extraction of Oils

The results in Table 1 show that wild melon seeds yielded 56.3% oil and calabash seeds yielded 55.2% oil. The seeds of wild melon generally contain 52-57% oil [16] therefore; the result of 56.3% in Table 1 is in order. This proves that calabash seeds do not contain much oil unlike wild melon seeds.

Characterization of the Seed Oils

The results of the characterization of the oils and blends are presented in Table 2. The calabash oil produced the highest flash point of 310⁰C, followed by wild melon oil of 260⁰C and the blend 120⁰. Flash points indicate the temperature at which a lubricant gives off sufficient vapour to form a flammable mixture with air. Oil with high flash point withstands high temperature operations. This means that such oil is safer to handle and be moved from place to place. In this study calabash oil is safer to handle than wild melon oil and the blend oil. This is because the calabash oil is less volatile than and the wild melon oil and blend oils.

The fire points of calabash oil, wild melon oil, and the blend in this study are 350⁰C, 325⁰C, and 250⁰C respectively as seen in Table 2. Since fire point is the lowest temperature that particular oil will sustain burning for five seconds, blend oil with fire points of 250⁰C have the ability to ignite flame easily and sustain burning for five seconds more than calabash and wild melon oils. That mixture stands the best oil sample, though higher than the minimum recommended ASTM value of 100⁰C.

The free fatty acids (FFA) values of the pure oils (S1 and S2) are 3.4% and 2.6% respectively and the blend 3.7%. High free-fatty acids content of the seed oils favours the production of grease as it reacts with metals to form soap. This means that the blend oil is the better than any of the pure oils in agreement with [17].

Table 3 shows the results of viscosity index of the sample oils. From the table, S2 (wild melon oil) has a viscosity index of 215, which is higher than the other sample oils. The high number, 215 could mean that the oil was highly refined and pure. According to [18], oils with higher viscosity index will remain stable and not vary much in viscosity over the temperature range, which allows for consistent engine performance within the normal working conditions. This means that wild melon oil is the best sample oil for lubrication and also good for grease manufacture. Generally, all the sample oils are suitable for lubricants because they are within the acceptable range of minus 60 to over 400 as reviewed [19].

The pour points of the sample oils are 10⁰C and 20⁰C S1 and S2 respectively. The pour point of the blend is 16⁰C (S3). The lower the pour points the better the ability of the oil to withstand extreme cold conditions. Such oil lubricates better in temperate region and transverse across regions without been affected by cold climates. It will have an easier start up than those with higher pour points. From the results therefore, calabash oil (S1) with the lowest pour point of 10⁰C is better than others to withstand cold condition and therefore could act as good base oil for grease to be used under extreme cold temperature condition. Pour point is an indication of flow of oils. That is why calabash oil at low pour point temperature is better for cold condition.

Analysis of Grease properties

The results of the viscosity temperature coefficient of the grease samples are shown in Table 4. The values are 0.2381, 0.2400 and 0.2290 for S1, S2 and S3 respectively. The smaller the viscosity temperature coefficient, the smaller the relative change in viscosity with temperature. The smaller the relative change in lubricant viscosities with temperature, the better the performance of the lubricant when subjected to great temperature changes experienced in practice. The lower the viscosity temperature coefficient is inversely proportional to viscosity index. It follows that calabash blended with melon base grease (s3) with the least viscosity temperature coefficient is the best among the three grease samples produced. It is less sensitive to temperature change.

The dropping point of soap-thickened lubricating grease is the temperature at which it passes from a semi-solid to a liquid state under specific conditions. It is an indication of the type of thickener used, and a measure of the cohesiveness of the oil and thickener of grease. It is used to determine the suitability of

greases for specific applications. From Table 5, calabash oil grease (s1) has a dropping point of 170⁰C, S2 has a dropping point of 168⁰C and S3 has a dropping point of 170⁰C. Looking at the results, the dropping point of the grease samples are relatively the same and so each of the oils or the blend could be recommended for use to produce grease.

Table 6 shows the penetration depth of the grease samples. Penetration goes with consistency of grease. The penetration depth is inversely proportional to the consistency number. S1 with penetration depth of 179 has consistency number 4 and stiff in nature. S2 and S3 with penetration depths of 315 and 325 respectively have the same consistency number 1 and are soft in nature. Greases with consistency number of zero (0) are said to be very soft or semifluid. Such grease does not have 'stay put' property. Such grease runs-off the lubricating surfaces, hence have poor lubricating properties. S1 with stiff nature may take longer time for the base oil to bleed out for lubrication.

According to Machinery Lubrication Guide [20], the most common NLGI grade is two (2), which is recommended for most applications. However, all the grease samples produced can be recommended for engineering applications.

Generally, one of the functions of the thickener (the metallic soap) is to hold the lubricating oil in a semi-solid state for easier handling. When there is rise in temperature, the oil bleeds out from the thickener and functions as a lubricating agent, and when the temperature drops again, the thickener soaks up the oil to become semi-solid once more. Grease such as (S1) cannot effectively be used under cold condition, especially during start-up condition.

Multiple Regression Modeling

Table 7 shows the predicted and experimental viscosity index. Table 8 shows regression coefficients for the multiple regressions using Reglin Function. Inside the table are values for viscosity index of the grease samples. Table 9 shows the predicted and experimental viscosity index of the grease samples... Figure 1 shows comparison of experimental and predicted viscosity index. Figure 2 shows correlation of experimental and predicted viscosity index and Figure 3 shows the correlation of predicted and experimental viscosity index using multiple regressions.

The test RMSE provides information on the short-term performance of the studied model as it allows a term by term comparison of the actual deviation between the predicted value and measured value. [21] Recommended that a zero value for MBE is ideal and low RMSE is desirable.

The multiple regression equation was developed for prediction of viscosity index (VI);

$$VI = -110.981 - 0.0234X_1 - 0.0385X_2 - 3.1678X_3 - 7.9171X_4 - 0.6652X_5 + 474.14X_6 + 0.0565X_7 + 3.5168X_8 - 0.0158X_9 + 3.49 \times 10^{-12}$$

This equation was used to predict the values of viscosity index presented in Table 9. The Table also showed statistical analysis for the validation of the model such as Mean bias error (MBE) and Nash-Scutcliffe efficiency (NSE). As shown in Table 8 the regression coefficients for, cloud point, viscosity temperature coefficient, mechanical stability and kinematic viscosity at 100⁰C, gave positive indicators while those of thickener, additives free-fatty acid, density and penetration gave negative values for viscosity index. According to [22] negative values of a multiple regression constants implies that as the independent variables increased the dependent variable decreases; thus this implies that as the thickener, additives free-fatty acid, density and penetration increased viscosity index decreases while viscosity index increased with increase in cloud point, viscosity temperature coefficient, mechanical stability and kinematic viscosity at 100⁰C. The values of statistical indicators MBE, and NSE for validation of the multiple regression model for

prediction of viscosity as shown in Table 9, show that the prediction of viscosity index employing the multiple regression model was satisfactorily with the values of, MBE, reasonably low, and NSE values reasonably high at almost all measured values and the overall error between the predicted and experimental values being 3.49×10^{-12} .

Figure 1 shows the visual assessment of the predicted and experimental viscosity index. The predicted values by multiple regression models matched with the experimental values. This was confirmed by the regression of the predicted and experimental viscosity index as shown on Figure 2. There was high correlation between the predicted and experimental with R^2 of 1.0000 for viscosity index. Hence, the visual assessment as presented clearly showed that multiple regression model was successful in modelling the viscosity index. Correlation between experimental and predicted viscosity index is positive and high ($r=0.96$).

CONCLUSION

Based on the results of the analysis carried out the base oils and blends are suitable for the production of greases that are bio-degradable and that the greases produced are suitable for engineering applications. These greases can be used as an alternative to petroleum base grease.

RECOMMENDATIONS

From the studies carried on the topic titled: Performance evaluation of greases produced from wild melon and calabash seeds, the following recommendations are given:

- Other renewable oil bearing plants should be explored;
- Tests such as friction at low temperatures, running at high temperatures and high speeds, quiet running behavior, lubrication film load capacity etc. which could not be carried out in this work because of lack of equipment are equally important and should be carried out for further work
- Rheological Evaluation such as viscosity, shear stress and shear strain of Grease Samples should be carried out for further work.

Table 1: Percentage Oil Yield

Seeds	Quantity used (kg)	Quantity of oil extracted (kg)	Percentage oil yield
Wild melon	8.0	4.5	56.3
Calabash	10.5	5.8	55.2

% moisture content for calabash seeds = 12.5, % moisture content for wild melon seeds = 11.1

Table 2: Characterization of Seed Oils and Blend

Properties	S1	S2	S3
Flash point ($^{\circ}\text{C}$)	310	260	120
Fire Point ($^{\circ}\text{C}$)	350	325	200
Free fatty acid %	3.4	2.6	3.7
Kinematic viscosity@40 $^{\circ}\text{C}$	89	275	460

Kinematic viscosity@100 ⁰ C	21	65	109
Pour point (⁰ C)	10	20	17

S1 = Calabash oil, S2 = Wild melon oil, S3 = mixture of Calabash oil & wild melon oil (1:1)

Table 3: Characterization of Sample Oils and Reference Oil

Properties	S1	S2	S3	Ref
Flash point (⁰ C)	310	260	120	270
Kinematic viscosity@100 ⁰ C	21	65	50	38.5-42.5
Pour point (⁰ C)	10	20	17	-9
viscosity index	155	215	212	95

Table 4: Apparent Viscosities of Sample Greases at 40⁰C and 100⁰C and their Viscosity Temperature Coefficients

Sample	Apparent Viscosity @ 40 ⁰ C	Viscosity @100 ⁰ C	Viscosity Temperature Coefficients
S1	147	112	0.2381
S2	350	266	0.2400
S3	345	266	0.2290

Table 5: Analysis of Grease Properties

Properties	S1	S2	S3
Penetration@ 25 ⁰ C (10ths of mm)	179	315	325
Dropping point	170	168	170
Apparent viscosity (Cp) @ 40 ⁰ C	147	350	345
Apparent viscosity (Cp) @ 100 ⁰ C	112	266	266

Table 6: Penetration of Grease Samples

Sample	Penetration (mm)	NLGI consistency no.	Nature of grease
S1	179	4	Stiff
S2	315	1	soft
S3	325	1	Soft
Ref. grease	230	3	medium

Table 7: Predicted and Experimental Viscosity index

S/N	Experimental Viscosity index	Predicted Viscosity index	NSE	RMSE	NMSE	MBE
1	70	69	1.0000	0.3160	1.0×10-6	-1.0000

2	236	238	0.9980	0.6320	4.0×10^{-8}	2.0000
3	216	216	1.0000	0.0000	0.0000	0.0000
4	165	168	0.9999	0.9490	1.05×10^{-5}	3.0000
5	370	370	1.0000	0.0000	0.0000	0.0000
6	362	362	1.0000	0.0000	0.0000	0.0000
7	362	360	0.9985	0.6320	1.0×10^{-6}	-2.0000
8	358	361	0.9999	0.9490	1.05×10^{-5}	3.0000
9	356	259	0.9985	0.9490	1.05×10^{-5}	3.0000
10	358	358	1.0000	0.0000	0.0000	0.0000

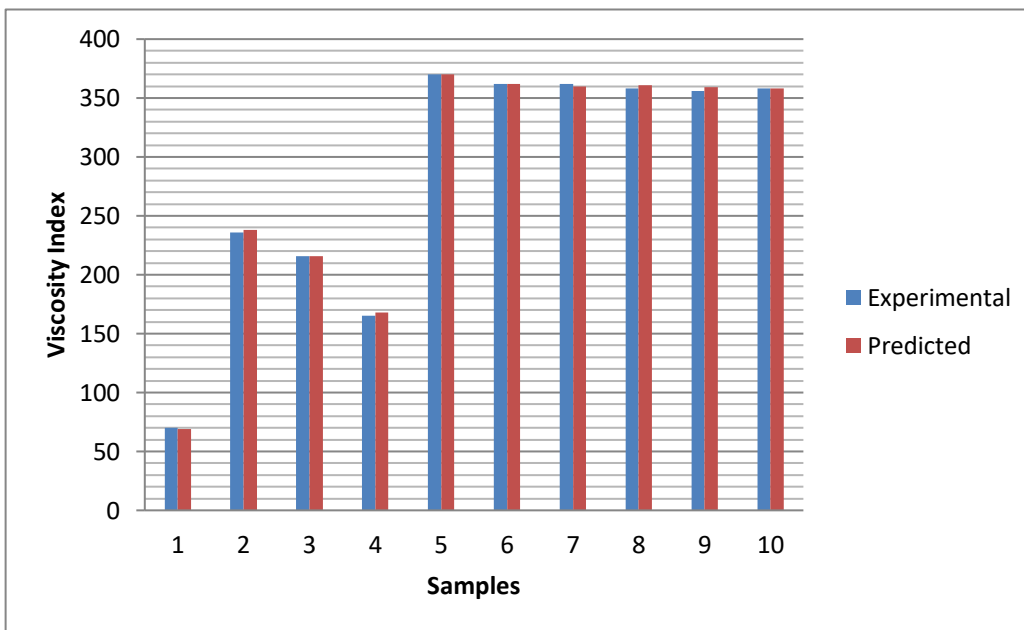


Figure 1: Comparison of experimental and predicted viscosity index

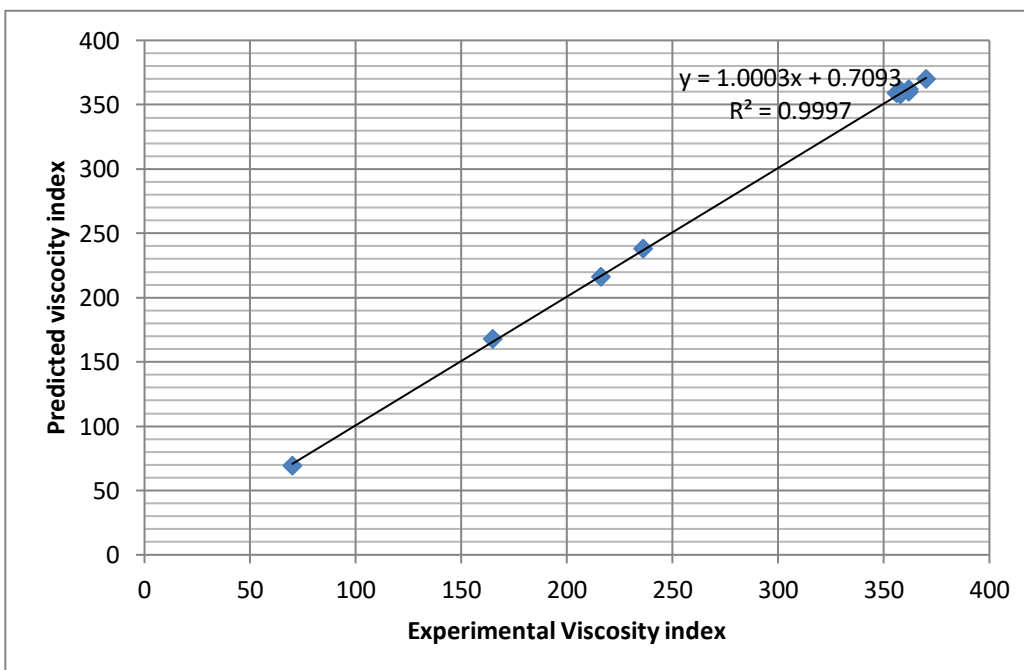


Figure 2: Correlation of predicted and experimental viscosity index.

Table 8: Regression Coefficients for the Multiple Regression using Reglin Function

S/N	COEFFICIENT VALUE FOR VISCOSITY INDEX
β_0	-110.981
β_1	-0.0234
β_2	-0.0385
β_3	-3.1678
β_4	-7.9171
β_5	0.6652
β_6	474.145
β_7	0.0565
β_8	3.5168
β_9	-0.0158

Table 9: Predicted and Experimental Viscosity index

S/N	Experimental Viscosity Index	Predicted Viscosity index	MBE	NSE
1	70	70	0.000	1.0000
2	236	234	-0.300	0.9887
3	216	216	0.0000	1.0000
4	165	164	-0.1000	0.9987
5	370	370	0.0000	1.0000
6	362	362	0.000	1.0000
7	362	362	0.0000	1.0000
8	358	358	0.0000	1.0000
9	356	356	0.0000	1.0000
10	358	358	0.0000	1.0000

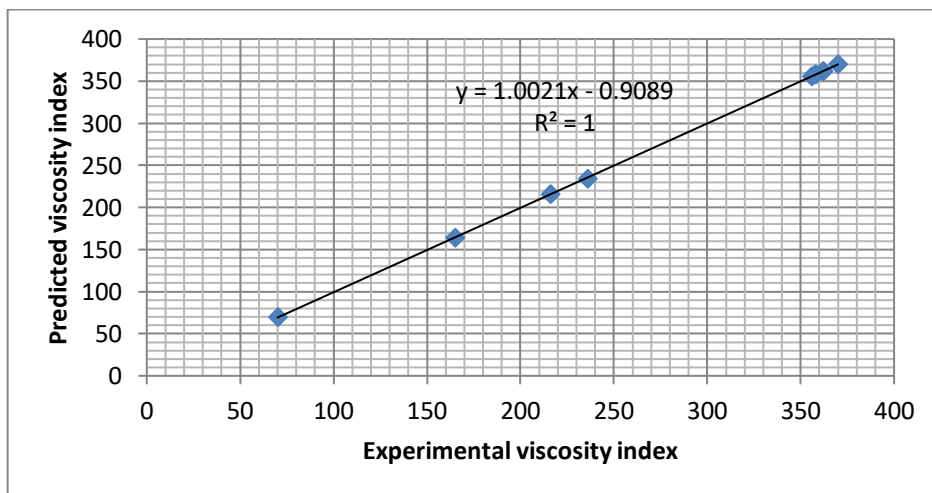


Figure 3: Correlation of Predicted and Experimental Viscosity Index using Multiple Regressions

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