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PARAMETRIC STUDIES OF BIOLUBRICANT PRODUCTION FROM PALM KERNEL OIL

Musa U., Mohammed I.A., Auta M., Gana E.M., Ahmed A.N and Ibitoye J.O

Department of Chemical Engineering of Federal University of Technology, PMB 65, Minna Niger State
umar.musa@futminna.edu.ng, ma.ibrahim@futminna.edu.ng, manaseauta@yahoo.com, esther.menegbe@yahoo.com, ahmedfut2012@gmail.com, ibitoyejo@gmail.com
Corresponding author email address: umar.musa@futminna.edu.ng

ABSTRACT

The study presents the transesterification of Palm kernel oil (PKO) and trimethylopropane (TMP) to biolubricant. The PKO was characterized for its acid value, % free fatty acid (FFA) and viscosity. Two stage transesterification was subsequently used for the biolubricant production. In the first stage the PKO was pre treated to reduce FFA. This was followed by the transesterification of biodiesel with trimethylolpropane (TMP) into biolubricant. The effect of temperature (100-150 ^{o}C), time (30 – 180 mins) and catalyst concentration (0.25 - 1.25 wt %) were studied. The biolubricant was characterized. Characterization of PKO revealed a high acid value which was substantially reduced to below 1 % by esterification before transesterification to methyl ester. The study revealed that 90 % of biolubricant was obtained at an optimum temperature, time and catalyst concentration of 120 ^{o}C, 60 mins and 0.5 wt % respectively. The lubricant properties such as flash point, pour point, viscosities at 40°C and at 100°C, and the viscosity index were determined to be -249 °C, 19°C, 40.9 cSt, 9.1 cSt and 241 °C respectively. The Biolubricant synthesized compares favourably with the ISO VG thereby establishing the potential of the biolubricant as gear oil except for the deviation in pour point.

KEYWORDS: Biolubricant, Biodiesel, Transesterification, Characterization, Palm kernel oil (PKO), Trimethylolpropane (TMP)

1.0 INTRODUCTION

Lubricants are used for the suspension of contaminant, transfer of heat, liquid sealing and corrosion prevention (Nie, 2012). Lubricants overtime during usage lose their lubricating properties and therefore; must be disposed and replaced. Large quantity of mineral oil based lubricating oils are used on daily basis, thus the disposal of usage lubricant has now become a global challenge (Udone, 2010). Strict governmental rules and increasing in public awareness for pollution free environment has led to an increase in the use of eco-friendly products like biodiesel and biolubricant for industrial application (Lathi, and Mattiasson, 2007; Dodos *et al.,* 2011). Besides this petroleum crude oil which is source of mineral base oil are subject to depletion (Amit and Amit, 2012). Vegetable oil are presently been perceived as an alternative to mineral base oil owing to their environmentally friendly properties such as biodegradability, non toxic and renewability. Vegetable oils have the greatest potential to replace mineral oil in the chemical industry (Anders, 2006). Vegetable oil may not be a viable total replacement for fossil fuels in transportation and energy usage because it is not possible to produce enough triglyceride oils to substitute for more than 10 % of current petroleum consumption. Currently, over 125 million metric tons per year of vegetable oils are produced worldwide which is about 3% of worldwide consumption of petroleum oil in 2007. Thus, it would be more appropriate to market oilseed crops in high-value applications such as industrial raw materials and lubricants (Yao, 2009). Vegetable oil are also characterize with high viscosity index, low volatility, high flash point and good lubricity. However, its characterized with low performance stability have largely limits its application in the lubricant industries. This includes hydrolytic instability, low oxidative and poor thermal properties (Salimon and Asmaa'Ishak, 2012). The presence of β hydrogen

atom in the hydroxyl group of the glycerol is the major cause of these performance limitations (Musa *et al.,* 2015). However these inherent problems associated with the use of vegetable oils for lubrication can be solved by combining the oil with additives or through chemical modification such as esterification, epoxidation, hydrogenation and transesterification (Salimon and Asmaa'Ishak, 2012).

During transesterification, the glycerol is replaced by an industrial polyol. The main advantage of using a polyol as a replacement for glycerol is the absence of β-hydrogen in the polyol which results into enhanced thermal stability of the lubricant at high temperatures by preventing self-polymerization (Phani *et al.,* 2013). Production of biolubricant from different seed oil with trimethylolpropane (TMP) as the polyol has been severally reported; Rapeseed oil based lubricant (Uosukainem *et al.,* 1998), Jatropha oil biolubricant (Resul *et al*., 2001; Ghazi *et al.,* 2010; Arbain and Salimon, 2011), Transesterification of palm oil- based methyl esters with trimethylolpropane (Yunus *et al.,* 2003; Kamil and Yusup, 2010) Biolubricants derived from methyl oleate and canola biodiesel (Phani *et al.,* 2013). Soyabean base oil lubricant (Oh *et al.,* 2013), Castor oil based lubricant (Musa *et al.,* 2015).

Palm kernel oil, coconut oil and palm oil are three of the few highly saturated vegetable fats, containing manly palmitic acid. Palm kernel oil is derived from the kernel of the oil palm. The oil is known for it several potential among which are its use for biodiesel and bio-lubricant production. This study is aimed two step base-catalyzed transesterification of palm kernel oil with a trimethylolpropane (TMP) as a branched polyol in the presence of sodium hydroxide as catalyst.

2.0 METHODOLOGY

2.1 MATERIALS

The palm kernel oil was purchased from a market at kogi state. Sulphuric acid (98% purity) was obtained from WAFT Department, pellet of NaOH was obtained from WAFT department, Methanol (99% purity) was purchase from Panlac, Trimethylolpropane (TMP), pellet of NaOH from Chemical Engineering Department and all reagents used were of analytical grade.

2.2 METHODS

2.2.1 Methyl Ester Synthesis

The methyl ester was synthesized via acid – base transesterification

2.2.1.1 Acid esterification (Pretreatment)

Five hundred (500) ml beaker was used as laboratory reactor for this experiment. 100ml of crude PKO was poured in to 500ml conical flask; 200ml of methanol and 0.5 % of sulphuric acid were measured and mixed with the crude PKO at a ratio of 6:1 respectively. This mixture was continuously heated and stirred in water bath equipment at a temperature of 55 ^{o}C. This was done for one hour under atmospheric pressure. The mixture was then poured in a separating funnel and was allowed to separate to get the pre-treated oil, acid and methanol separated. The free fatty acid was measured and found to be tolerable for transesterification.

2.2.1.2 Base Transesterification

In this step; same experimental set up used for the acid pre-treatment or acid esterification was also used for this step. The palm kernel oil Methyl Esters (PKOME) prepared by methanolysis of palm kernel oil using sodium hydroxide (NaOH) pellet as catalyst at a concentration of 0.5 wt% of oil. The sodium methoxide was prepared by dissolving 0.1g of sodium hydroxide pallet base on weight of oil was added to a conical flask containing 20 ml of methanol which was totally dissolved by shaking thoroughly and swirling slightly to form sodium methoxide before being added to 100 ml of pretreated PKO, this was then covered with a foil in order to control loss of methanol. The mixture was kept at water bath and heated with continuous stirring at 60 ^{0}C. The samples were poured into a separating funnel at which two layers were observed. However the lower layer contains impurities and glycerol while the upper layer contain impure biodiesel yield. The impure biodiesel is then withdrawn for purification and then washed with distilled warm water to remove the sodium hydroxide content from the sample. This was repeated continuously until the warm water became clear. The PKOME mixed with water withdrawn from the funnel was then dried in the oven to evaporate residual water content.

2.2.1.3 Synthesis of Biolubricant

The palm kernel methyl ester was weighed and poured into the three neck flask fitted with a reflux

condenser, vacuum pump, thermometer and mounted on a magnetic stirrer hot plate. The reacting system was then heated to and maintained at 120^{0}C and 3.2g of TMP was added to the flask containing biodiesel followed by the gentle addition of KOH catalyst to the mixture of trimethylolpropane and methyl ester under vacuum condition for 1 hour. As the reaction proceeds the biolubricant and methanol as a co-product were formed. The methanol evaporate and was collected via the the condenser into a flask bottom flask. This process was carefully monitored throughout the production. The process was repeated at different time (30, 60, 90, 120, 150 and 180 minute), different temperatures (90,100,110,120,130 and 140 ^{o}C) and catalyst concentration 0.25 to 1.25 wt %.

2.2.2 Characterization of the palm kernel oil trimethylolpropane ester

The physical properties of the oil were characterized using AOACS standard method while the biolubricant syntheisized was characterize according to the ASTM Standard .

3.0 RESULT AND DISCUSSION

3.1 EFFECT OF PROCESS VARIABLES

The results of effect of time, temperature and catalyst concentration variation as a fuction of biolubricant yield are clearly represented in Figure 1-3.

3.1.1 Effect of reaction time

In this study the effect of reaction time was studied between 30 and 180 minute.

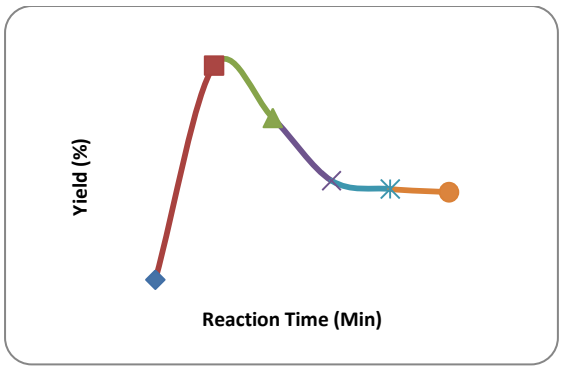

Figure 1: Effect of reaction time on the yield of palm kernel oil TMP tri-esters

The biolubricant yield increases progressively from 78.9 % at 30 min to 85 % at 60 minute. Further increase in reaction time beyond 60 minute leads to a decrease in the yield of biolubricant obtained. This result differs significantly with the work of Chandu *et al.,*(2013) who reported an optimum time of 3hr. The difference in yield obtained can be attributed to difference in the process condition and feedstock, used in the transesterification process. It was deduced from this study that increase in reaction time in the synthesis of biolubricant from palm kernel oil methyl ester beyond 1 hr certainly resulted into a continuously decrease in the polyol ester yield, thus 1 hr is reported as the optimum time for this synthesis.

3.1.2 Effect of catalyst concentration

This research investigates the effect of catalyst concentration from 0.25 – 1.25 wt% base on the quantity of methyl ester used. The variation was increase progressively at an interval of 0.25 wt%.

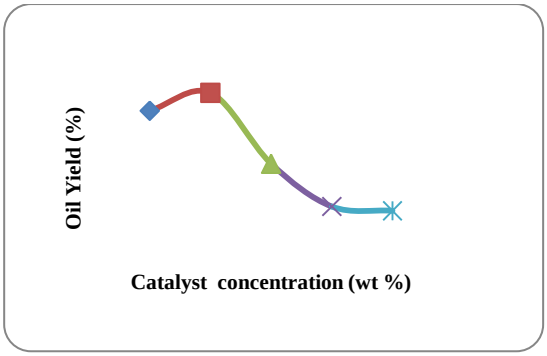

Figure 2: Effect of alkaline catalyst on percentage yield

From Figure 2 the result shows that increase in catalyst concentration from 0.25 – 0.5 wt% resulted in to an increase in bio lubricant produced; this yield increase from 79.83 % at 0.25 wt% to 89.1 % when 0.5 wt% of catalyst was employed in the transesterification process at temperature of 120 ^{o}C, reaction time of 1 hr and a mole ratio methyl ester to TMP of 4:1. When the catalyst concentration was increased beyond 0.5 wt% NaOH concentration a progressive decrease in TMP ester was continuously observed until it stabilizes at 1.25 wt%. This decrease is clearly due to the observed formation of emulsion as the catalyst concentration increases beyond 0.5 wt%. This result agree quite well with the literature of Yunus *et al,*(2003) who stated that higher amount of catalyst leads to solidification of the resulting product.

3.1.3 Effect of reaction temperature

Temperature is known to play a positive role in the synthesis of polyol ester. In this present study the effect of temperature was investigated from 110 – 150 ^{o}C at a progressive 10 ^{o}C increase, while keeping the catalyst concentration constant at 1 wt% of KOH, time of 1 hr.

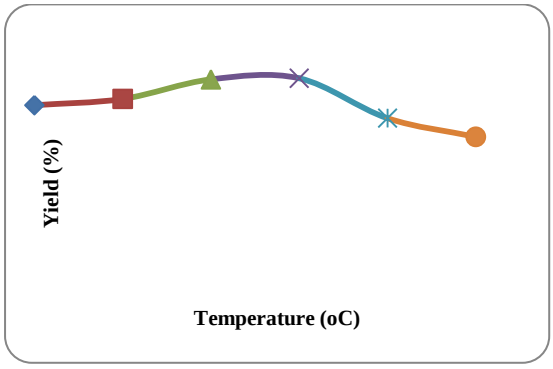

Figure 3: Effect of reaction temperature on yield of palm kernel oil TMP tri esters

The yield of PKO derived lubricant shows a linear increase from 100 – 120 ^{o}C. The yield increase from 76.17 % to 84.16 %, further increase in temperature to 130 ^{o}C has no significant effect of the yield obtained. However, a further increase in temperature above 130 ^{o}C shows a drastic decrease in the biolubricant yield as depicted in Figure 3.

The result depicts that higher temperature beyond 120 ^{o}C are not desirable in the synthesis of biolubricant from PKO.

3.2.2 Characteristics of lubricant

Table 2: Properties of palm kernel oil biolubricant

Properties	Pour point (^{o}C)	Flash point (^{o}C)	Viscosity @40 ^{o}C	Viscosity @100 ^{o}C	Viscosity index
This study	19	249	40.9	9.8	201
ISO V46	-10	220	>41.4	>4.1	>90
Palm Kernel oil	28.75	-	32.50	-	-
A	-12	-	35.43	7.93	206
B	-66	-	40.5	7.8	204
C	11.8	-	-	16.1	67

[A] Dodos *et al.,*(2011), [B] Mohammed *et al.,* (2011), [C] Linxing Yao., 2009

The resulting bio based lubricant was characterized for it's lubricating properties as shown in Table 2 and the lubricant has flash point of 249 °C, pour point of 19°C, viscosities at 40°C and 100°C were 40.9 and 9.8 and the viscosity index of 201. These properties show reasonable agreement with ISO VG standard for light gear oil except for the deviation in pour point value.

4.0 CONCLUSION

Palm kernel oil was used as a feed stock in this study for the synthesis of biolubricant. The study of the effect process variables investigated on biolubricant yield show that optimum time was 1hr, catalyst concentration of 0.25 wt% and a temperature of 120 ^{o}C at this condition a maximum yield of 90 % PKO derived lubricant was obtained at a mole ratio constant of 4:1. Characterization of the synthesized lubricant shows that the product can be used as motor gear oil.

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7.0 BIOGRAPHY OF LEAD AUTHOR

Umaru Musa is an academic staff with the Federal University of Technology Minna, Nigeria. He first obtained a National Diploma in Chemical Engineering from Federal Polytechnic Bida, Niger State in1997. He later obtained a Bachelor and Masters Degree in Chemical Engineering from the Federal University of Technology Minna, Nigeria in 2006 and 2013 respectively. His major area of research interest is Sustainable Energy Development and Utilization (Biofuel Production Technology), Environmental Engineering and Material Science". He has published several articles in peer reviewed Journals, attended and presented a number of papers at both local and international conferences. He also has a book chapter published with springer. He is a member of Nigerian Society of Chemical Engineers (NSChE), International Association of Engineers (IAENG).