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Transesterification of Non-Edible Vegetable Oil for Lubricant Applications in Water-Based Mud: A Review

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Abstract

The deterioration of the environment as a result of the disposal of oil-based mud used in the oil industry in offshore and onshore environment is alarming and preventive measures must be taken to protect it. Vegetable oil as biolubricant in water-base mud has proved to have potentials in formulating drilling mud for oil and gas exploration due to their inherent properties. Nevertheless, the direct usage of this plant oil is limited in application due to their high viscosity, unstable hydrolytic and oxidative effect. These parameters can be improved upon through transesterification process.

This paper hereby review the derivable benefits of chemically modifying vegetable oil inorder to improve their physicochemical properties through transesterification reaction process, and the effect it will have when applied to drilling mud.

Keywords: Transesterification, Lubricant, Biolubricant, Vegetable Oil, Water-based Mud, Oil- based mud

INTRODUCTION

The performance efficiency of drilling mud is dependent on the type and quality of additives used. The functions of drilling fluid are to: increase the lubricity of the mud thereby preventing high torque and drag, and sticking of bit and drillstring; carry cuttings generated from the buttonhole to the surface; enhance removal of the cuttings in the mud at the surface; prevent destruction of the permeable zones; control formation pressures that may lead to kick and blowout; maintain strength of the formation; prevent challenges during well logging operations; reduce corrosion of the subsurface drilling equipment; reduce torque and drag that may lead to stuck pipe; and to support drill pipe penetration rate (Adams & Charrier, 1985). There are basically two types of mud in the oil and gas drilling industry. The water-based mud (WBM) uses water or brine as the continuous phase (Bakhtyar & Gagnon, 2012). They are the largely used in the industry because they are easy to formulate and cost effective to dispose due to the low treatment cost (Dosunmu & Joshua, 2010). Oil-based mud (OBM) uses oil as the continuous phase. It uses crude or refined oil and they have water emulsified in the oil. OBM are widely used in wells that are prone to drilling problems such as formation damage due to interaction because it performs better than the WBM (Dosunmu & Joshua, 2010).

The OBM provides good stability in shale zones and well, good lubricity efficiency for faster rate of drill pipe penetration, thermal stability, lowers rate of corrosion, reduce risk of stuck pipe and low formation damage, lower friction and torque values etc. than the water-based mud. However, their application is limited by the cost of processing and environmental issues they caused when disposed on land or sea (Sönmez et al., 2013). In providing solution to this, researchers have proposed the use of a WBM formulated with lubricants that is environmentally friendly, cost effective and lubricious as the OBM (Kania et al., 2015).

Some researchers have extracted vegetable oil from plant seed as lubricant and used directly in their mud formulation (Dosunmu & Joshua, 2010; Fadairo et al., 2012). However, this usage of vegetable oil without any modification or improvement in drilling mud is considered unstable or limited due to their flow behavior at low temperatures, unstable thermal and oxidative stability due to the presence of acyl groups and glycerol (Borugadda & Goud, 2016; Randles, 1994; Salimon et al., 2010). The aforementioned characteristics of fatty acid in vegetable oil limits the application of vegetable oils (Yao et al., 2010), it is highly viscous and exhibit poor cold flow behavior.

Atabani et al. (2013) made a review on the potential of using second generation feedstock also known as non-edible vegetable plant instead of the first generation for producing biodiesel. Emphases have been made on the challenges of these oils, their fatty acids analysis of various non-edible vegetable oils, different methods of extraction oil from their seeds, and physicochemical property analysis of biodiesel etc. The result of their review showed the potential of producing biodiesel from non-edible vegetable sources in the future due to their properties, performance, and emission characteristics. Jain and Suhane (2012) proposed the use of non-edible vegetable oils as an attractive alternative to petroleum oil-based lubricants. Oil varieties of such as *Jatropha*, *Moringa* and castor oil were chemically modified using transesterification process tailored to meet some certain properties in meeting or replacing petroleum-based lubricant in enhancing machining operations.

Lubricants are incorporated in drilling fluids to improve the lubricating effect of the mud, thereby reducing torque and drag between the drill pipe and the formation which can result into pipe sticking. The challenges of pipe sticking is a non-productive cost when encountered and hence, high lubricity drilling fluid is required in drilling operations as this will improve the drilling rate and minimize cost (Siruvuri et al., 2006). The most important function of lubricant is in their friction reduction ability, the transfer of heat and prevention of corrosion etc., drilling fluid with poor lubricating effect can lead to high torque and drag problems, poor wellbore instability and differential sticking (Siruvuri et al., 2006).

The base stocks for lubricant may be of petroleum, synthetics or vegetable oil (Mang & Dresel, 2007). The mineral oil based or industrial lubricant forms the major type of lubricant used in the oil industry. They are sourced from petroleum oil and constitute 95% of the lubricants used in the world (Luna et al., 2011). One major characteristic of lubricant is its viscosity, because this is the fluid property responsible for preventing contact and reducing friction between different surfaces. Other properties are solubility with other base oils, toxicity, hydrolytic stability, oxidation stability, corrosiveness, flammability, and environmental effects (Mang & Dresel, 2007). Studies have also shown that waste hydrocarbon-based lubricant are disastrous to human and the surrounding, and are less biodegradable (Getliff & James, 1996; Martin et al., 2006; Neff et al., 2000). In ensuring safety of the environment, the drilling companies are advised to explore the greener lubricant applications with through offshore and natural drilling regulations on drilling fluid (Kania et al., 2015). .

Biolubricants possesses suitable properties such as excellent lubricity over the conventional mineral oil lubricant. This is attributed to their polar nature which enhances their bonding ability to the metal, resulting in substantial increase in thin film strength. The wetting reduces friction and by this, energy is saved from 5 to 15% of the equipment operation (Bilal, 2013). They also have higher viscosity index, a property dictates the use of a lubricant in drilling operations as high temperature formations are being encountered. The viscosity index of biolubricants qualifies them when applied in conditions of temperature equal or above 250 °C (Bilal, 2013). Biolubricants are less volatile, with high flash and fire points, coupled with less vapor emissions. They are biodegradable and do not pollute the marine environment. This property widens their application in offshore environment, and their non-water polluting characteristic leads to considerable cost of disposal. Despite the advantages of biolubricant, there are prevailing disadvantages which can be managed to an extent. They produce some offensive odour. Also, if contaminants are present, the viscosity values are usually high at low temperatures which may affect proper hole cleaning and increase the equivalent circulating density, thereby increasing cost. There may be limited availability of feedstock if raw materials are not available (Bilal, 2013).

André (2011) showed the production of biodegradable lubricants through transesterification process. The environmentally friendly nature, with regulations in favor of the biolubricant production over the mineral-based lubricant is a drive for the potential use of biolubricant. Kamil et al. (2011) investigated the optimization process of producing polyol ester by transesterification reaction of *Jatropha curcas* oil methyl ester with trimethyl propane using Taguchi design of experiment. Ong et al. (2011) made a review on producing biodiesel from palm oil, *Jatropha curcas* and *Callophyllum inophyllum* for biodiesel.

THE ENVIRONMENTAL ACCEPTANCE OF BIOLUBRICANT

In Germany, Austria, and Switzerland; laws and regulations are enacted to encourage the use of biolubricants thereby discouraging hydrocarbon-based lubricants. The Swedish City of Gothenburg encouraged manufacturing industry to use biolubricants. In the Scandinavian countries, ventures using biolubricants were exempted from tax. In Italy, tax is placed on petroleum oils and their sub-products. In 1996, within the United State of America, the agricultural sector proposed guidelines for items developed from bio-based products, as required under Act 2002-Farm Security and Rural Investment (Randles, 1994).

In this regard, there is a need to explore the use of biolubricants as they are biodegradable, environmentally friendly and has a net zero greenhouse effect (Jain & Suhane, 2012). The exploration of vegetable oils for biolubricant is on an increasing demand due to the positive environmental impact and non-toxic effect it has on land and in the sea. The use of non-toxic lubricants having tendency to be degradable by their microorganisms have gain recognition over the past 25 years (Willing, 2001). The exploitation of biolubricant reduces dependence on non-renewable resources and increases the demand for agricultural products, thereby reducing unemployment in the agricultural sector etc.

TRANSESTERIFICATION OF VEGETABLE OIL

Transesterification is the common process responsible for converting triglycerides to biodiesel. It is a chemical modification process that transforms the large branched molecule structure of vegetable oils into smaller, straight chained molecules similar to the conventional diesel oil (Schuchardt et al., 1998). It is the process of reaction that causes a change in the organic group R" of an ester with the organic group R’ of an alcohol under the influence of an acidic or basic catalyst (Schuchardt et al., 1998). The chemical modification is a combination of esterification process aimed at reducing the free fatty acids content of vegetable oil to less than 2 wt.%, followed by the transesterification reaction which is to convert the vegetable oil to methyl ester in order to qualify it as base oil for formulating mud (Sulaimon et al., 2017).

Abdul Habib et al. (2014) used the transesterification chemical modification process for the synthesis of palm oil. The properties of the synthesized oil was analyzed for improvement and validated using the API 13B specifications before the formulation of the drilling fluids. The palm oil methyl was transesterified with 2-ethylhexanol to produce palm oil-based ethylhexyl ester in less than 30 mins. The formulations were analyzed using rheological properties, filtration properties, and some physical and chemical properties. It was discovered that the synthesis of palm oil for base oil in drilling operations is a potential base fluid for drilling fluid.

IMPACT OF TRANSESTERIFICATION CHEMICAL MODIFICATION ON THE PROPERTIES OF VEGETABLE OIL

The purpose of esterification of vegetable oils is to acquire desirable optimum mud properties such as suitable viscosity index, high coefficient of friction, high film strength, lower corrosion rate, adequate pour point, less flammable, thermal stability, solubility, oxidative stability, and non-toxic. Bilal (2013) extracted oil from *Jatropha* seeds and chemically modified it using two-stage transesterification process for the production of biolubricant. The first stage produces the methyl ester while second stage uses the *Jatropha* oil methyl ester to produce polyol ester. The crude and synthesized *Jatropha* oil were characterized to compare their properties such as the density, acid value, free fatty acid, saponification value, viscosity at 40 °C and 100 °C. The properties were all compared to the ISO (VG-46) viscosity grade 46 to determine their performance for biolubricant production. Result reveals that the viscosity of the chemically modified *Jatropha* biolubricant were slightly higher than that of the *Jatropha* crude oil which also met the ISO VG-46 grade, the viscosity index value (195.22) for the biolubricant reveals a minimal temperature changes at higher temperature, the pour point of the modified biolubricant (-7 °C) improved from 5 °C for *Jatropha* crude oil.

- **The Impact of the Modification on the Viscosity of Vegetable Oil**

The high viscosity of vegetable oils is one negative effect caused by hydrogen bonding. The presence of the hydroxyl group causes an increase in the intermolecular interaction leading to high viscosity of the oil samples. Dosunmu and Joshua (2010) suggested the use of esterification reaction process in optimizing the viscosity of vegetable oil thereby enhancing their performance in mud operations. This is on-going research in improving vegetable oils so that they can be compared to and be a good substitute for petroleum based lubricants. The effect of transesterification reaction is to reduce the intermolecular forces on the bond thereby reducing the viscosity of the oil product

- **The Impact of the Modification on the Pour Point of Vegetable Oil**

One important property of potential vegetable oil for biolubricant is their pour point, This low temperature flow property of vegetable oil is poor and therefore limits their applications to be used as industrial fluids. The chemical modification on the karanja oil exhibited an improved pour point compared to when it wasn't modified at reduced temperature (Singh & Chhibber, 2013). The improvement in the pour point is as a result of the removal of the polyunsaturation and increase in the chain length.

- **The Impact of the Modification on the Oxidative Stability of Vegetable Oil**

Salimon et al. (2014) made a review on the synthesis of biolubricants by epoxidation, oxirane ring opening, and esterification reaction of the fatty acids of *Jatropha curcas* oil, soybean oil, and canola oil etc. to improve their oxidative and thermal stability. The oxidative stability was improved by modifying the chemical structure of the compound by transforming the alkene group to stable functional group and attaching alkyl side chains, thereby improving their performance at low temperature. Salimon et al. (2010) made a review on biolubricant, their environmental impact, the raw materials, and the need to chemically modify the biolubricant instead of using it directly. The chemical modification processes spoken of are epoxidation of the carbon-carbon double bond, estolides of oleic acid and saturated fatty acids. The modification process was made to solve the challenges of unstable oxidative stability despite their unique properties of lubricity, high viscosity indices, superior anticorrosion properties induced by adhering ability to metal surfaces, and high flash point of over 300 °C which made them non-inflammable.

Sharma et al. (2006) performed a structural synthesis of vegetable oils in order to enhance their oxidative and thermal stability which is one basic challenge in directly using vegetable oil as lubricants. Soybean oil was epoxidized which required chemical processes of opening the ring and further esterifying the compound thereby structurally modifying the molecular structure using acetic anhydrides. Modified vegetable oil exhibited superior performance in their oxidative and thermal stability at high temperatures.

THE PERFORMANCE OF TRANSESTERIFICATION ON VEGETABLE OIL IN IMPROVING DRILLING MUD OPERATION

Drilling mud with efficient lubricating effect will exhibit fluid properties such as relatively high viscosity in enhancing cutting carry capacity, high lubricating film strength in preventing friction and differential pipe sticking, high corrosion inhibition effect in preventing deterioration of the drill pipe and casing by corrosive formation fluid. They also possess properties of low pour point in enhancing free low of lubricant, low flammability in preventing fire hazards, high solubility performance in enhancing mixture with other liquid, high thermal stability to prevent deterioration of the rheological properties, high oxidative stability in preventing excessive viscosity of the fluid caused by reaction of the lubricant and oxygen at high temperatures, and environmentally friendly.

Kania et al. (2015) reviewed the development of biolubricants from organic sources and their application in drilling operations due to their favorable physicochemical properties of thermal stability, hydrolytic stability, oxidative stability, solvency, lubricity, viscosity and viscosity index etc. The modification process reveals lower torque and drag, good viscosity index, low pour point and flash point, low toxicity, and much more stability under heat.

Dardir and Hafiz (2013) prepared an environmentally friendly esteramide from the reaction of an unsaturated fatty acid compound of oleic acid and lauricamide (derived from reaction of lauric acid and diethanol amine). The rheological properties, high pressure high temperature (HPHT) filtration test, thermal stability test, and biodegradability test of the synthetic mud were investigated. Their result showed that the rheology of the formulated ester-based mud performed better than the synthetic ester based mud, the formulated ester-based mud exhibited a higher biodegradability and low toxicity than that of the field/synthetic ester-based mud, the thermal stability test showed that the formulated ester-based mud is more stable at high temperature than the imported or synthetic ester-based mud. The formulated ester based mud is not made from petroleum products and so the biodegradability is expected to higher than the synthetic ester based mud.

CONCLUSION

There are innate potentials in exploring non-edible vegetable plant oil as lubricant in formulating drilling mud. This will by far reduce cost and prevent the environment from been polluted. Many researchers have worked on the research potential of using vegetable oil, both edible and non-edible, but limited application of the transesterified vegetable oil in drilling mud operation is to the minimum. The chemical modification optimized the physicochemical properties by reducing the high viscosity challenge of vegetable oil. It also reduces the rate of oxygen absorption thereby enhancing the oxidative stability, and also prevents it from reverting back to acid and alcohol which is an improvement in the hydrolytic stability. The properties make vegetable oil function well as the diesel.

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