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EFFECTS OF TEMPERATURE ON THE VISCOSITY OF BIODIESEL EXTRACTED FROM CASTOR OIL

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Abstract

Biodiesel fuels were prepared from vegetable oil of castor beans and studied through viscosity. The crude castor bean oil was purified, trans-esterified. Fourier Transform Infrared spectra (FTIR) was used to examine the structures of the samples, the viscosity (both dynamic and kinematic) were studied. To make the oil more useful also to resist high temperature there is need to add an additive such as oxide based nano-particles, the nano-particles also will result in increase in the in thermal property and the viscosity of the oil. The viscosity change may have contributed to the observed increase in volatility the oil with temperature. Therefore, transesterified castor based nano-fluid can be a good coolant or good insulating oil due to its low viscosity which may be slightly higher than conventional insulating fluid because of high melting and boiling point of the oxide based nano particle.

Keywords: FTIR, lubricants, morphology, nanoparticles, oxide based, Vegetable oil, viscosity.

1. Introduction

Majority of the world's energy needs are supplied through petrochemical sources, coal and natural gases, with the exception of hydroelectricity and nuclear energy, of all, these sources are finite and at current usage rates will be consumed shortly [1-5]. Diesel fuels have an essential function in the industrial economy of a developing country and used for transport of industrial and agricultural goods and operation of diesel tractor and pump sets in agricultural sector. Economic growth is always accompanied by commensurate increase in the transport. The high energy demand in the industrialized world as well as in the domestic sector and pollution problems caused due to the widespread use of fossil fuels make it increasingly necessary to develop the renewable energy sources of limitless duration and smaller environmental impact than the traditional one [6,7]. Biodiesel, an alternative diesel fuel, is made from renewable biological sources such as vegetable oils and animal fats. It is biodegradable and nontoxic, has low emission profiles and so is environmentally beneficial [10].

However, it is known that petroleum product such as mineral oil will be eventually depleted in the future since it is a non-renewable source. With the concern on the fire safety and environmental issues, alternative fluids are currently being considered. Vegetable oil such as natural ester or synthetic ester is among the alternative fluids being considered. For years, various research works were carried out on different aspects such as on the safety environmental ageing and electrical performances of the vegetable oil. The vegetable oil was also successfully applied in-service where it was used from small to medium transformers up to a voltage level of 66 kV. Among the attractive factors of vegetable oil is the non-toxicity and highly biodegradable which ensure low risk to the environment if there is a spillage. The high flash and fire points of vegetable oil make it more safety than mineral oil [8,9].

Vegetable oils have become more attractive in the recent years owing to its environmental benefits and the fact that it is made from renewable resources. Vegetable oils are renewable and potential source of energy with an energetic content close to diesel fuel. Oils derived from vegetable sources may in course of time become as important as petroleum and the coal tar products of present time. Recent decrease in minerals oil prices and to the fear uncertainties concerning minerals oils availability renewed the interest in vegetable oil fluid for industrial application [12].

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Keeping this in mind, this research wishes to study the effects of temperature on the viscosity of the biodiesel extracted from castor oil.

2. Materials and Methods

2.1 Materials

Chemicals

The materials and reagents used in carrying out the research are as follows: crude castor oil, 8 % sodium hydroxide (NaOH), 64 % citric acid ($C_6H_8O_7$, purity: 99.7 %), Al_2O_3 nano-particles, activated carbon, acetone, and distilled water (H_2O).

Equipment

The equipment used in carrying out this study are: magnetic stirrer with thermostatically controlled rotary hot plate (IKA C-MAG HS10), Brookfield Digital viscometer {Brookfield,RVDV-I}, thermometer, measuring cylinder, Cheng Sang Vacuum oven (MA 0-30L), Digital weight balance (AND model GT2000 EC), beaker, 24 cm filter paper, funnel, Digital stop watch, sampling bottles, spatula.

3. Methodology

Purification

The crude castor oil was purified through the following procedure; 200 ml of the castor oil was measured using measuring cylinder; the oil was pre-heated to 70ºC using hot magnet stirrer with thermometer. 1.5 ml citric acid was measured and added to the heated oil sample and continuously heated and stirred for 15 minutes at 70ºC .4g of 8% NaOH (by dissolving in 100 ml of distilled water) was then be added to the oil and continuously heated and stirred for 15 minutes at 70ºC. The mixture was then transferred to the vacuum oven where it was heated at 85ºC for 30 minutes. Then the mixture was taken back to hot magnetic stirrer and heated to 70ºC after which a 2 g 0f silicone reagent was added while it was being heated and stirred for 30 minutes. Then the temperature was increased to 85ºC and 4 g of activated carbon was added to each 100 ml of the oil sample, heated and stirred for 30 munities. Then the mixture was separated using filter paper

Trans-esterification

60g of the crude castor oil was measured in 250ml of conical flask and was heated and stirred to a temperature of 60℃ - 65℃ on a hot magnetic stirrer plate, 0.6g of NaOH was measured using the electronic weight machine and allowed to dissolve in 21ml of methanol and then allowed to heat for 60 minutes with the stirrer on the hot magnetic plate. After 60 minute of uniform stirring and heating on the hot magnetic plate maintaining a temperature of 65℃, it was then poured into the separating funnel through a glass funnel. The mixture was allowed to cool for about 40 minute. Afterwards, it was observed that it separated into two liquid layers as shown on fig 8 and fig 9. The upper layer is the biodiesel and the lower layer is triglycrol fatty acid.

Samples Measurement

Specific gravity (S.G)

Specific gravity (S.G) is the ratio of the weight of the liquid to the weight of the equal volume of water

OR

The ratio mass of liquid to the mass of equal volume of water

OR

The ratio of density of liquid to the density of water at the same temperature.

Viscosity

Viscosity was measured using Brookfield viscometer in a speed range of 50 rpm with spindle size of 2, since a small quantity of the sample is to be measured. The following are the detailed procedure for viscosity measurement; the sample was poured into a beaker, the spindle was fixed and the machine was started, the angular speed was selected on the viscometer and the viscosity was read and recorded the same procedure was repeated for the purified transesterified castor oil.

Informally, viscosity is the quantity that describes a fluid's resistance to flow. Fluids resist the relative motion of immersed objects through them as well as to the motion of layers with differing velocities within them. There are actually two quantities that are called viscosity. They are dynamic and kinematic Viscosity [11].

Dynamic Viscosity

Dynamic (which is also known as absolute viscosity), represented by the symbol η, is the ratio of the shearing stress (F/A) to the velocity gradient (dv_x/dz) in a fluid.

$$\eta = \frac{\frac{F}{A}}{\frac{dV_x}{dZ}} \quad (1)$$

Where F is the force applied and A is the area.

The more usual form of this relationship, called Newton's equation, states that the resulting shear of a fluid is directly proportional to the force applied and inversely proportional to its viscosity. The similarity to Newton's second law of motion ($F = ma$) should be apparent [19].

$$\frac{F}{A} = \eta \frac{dvx}{dz} \quad (2)$$

$$F = \eta \frac{dv}{dt} \quad (3)$$

The SI unit of viscosity is the pascal second [Pa S]. The most common unit of viscosity is the dyne second per square centimeter [dyne s/cm2], which is given by poison. Ten poise equal one pascal second [Pa S] making the centipoise [CP] and millipascal second [mPa S] identical.

1 Pa S = 10 P
1,000 m Pas = 10 P
1 m Pas = 0.01 P
1 m Pas = 1 Cp

Kinematic viscosity

Kinematic viscosity is a measure of the resistive flow of a fluid under the influence of gravity. It is frequently measured using a device called a capillary viscometer. The kinematic viscosity (represented by ν) is the ratio of the viscosity of a fluid to its density.

$$\upsilon = \frac{\eta}{\rho} \quad (4)$$

Kinematic viscosity depends on the density of the fluid, while the dynamic viscosity is related to absolute viscosity (η) as a function of the fluid specific gravity (SG) according to the equations.

Temperature

The effect of temperature on kinetics and thermodynamics of reactions is unquestionable. Higher temperature almost always translates into faster kinetics and thus, the production of final products at a higher rate. However, this is not necessarily equivalent to better economics since increasing the temperature requires extra energy. More importantly, faster kinetics do not always correspond to better results as temperature also influences the selectivity of the products. In another word, one can obtain the products at a higher rate by raising the temperature, but the products obtained might not be the ones desired. This is in fact the case for deoxygenation processes. As the temperature rises, the reaction proceeds faster and the degree of deoxygenation increases significantly, both of which are favorable [6,14]. Nevertheless, high temperatures (typically >400 °C) give rise to undesired cracking (C4-C14) and heavy (C19-C30) products and reduce the yields of diesel fuel in the product stream [7,9,17]. They also increase the isomerization products that can improve the cold flow properties of diesel fuel at the expense of cetane number.

4. Results and Discussion

Specific Gravity

The specific gravity of the samples is calculated as was describe in the literature and the result is summarized on the Table1 below. It could be seen that the crude oil has highest specific gravity, followed by purified oil; transesterified has the lowest specific gravity. But all are within the limit of biodiesel standard and that of diesel standard. Specific gravity is one of the most important properties of fuels, because injection systems, pumps and injectors must deliver the amount of fuel precisely adjusted to provide proper combustion. It is an intensive property that is independent of the quantity, can be indicative of pure and can also be used to perform conversions by volume.

Table1: Result of Specific gravity

S/N	Sample	Specific gravity
1	Crude Castor oil	0.952
2	Purified Castor oil	0.945
3	Transesterified Castor oil	0.911
4	Biodiesel standard	0.903 to 0.921
5	Diesel standard	0.82 to 0.95

Viscosity

Viscosity is a measure of resistance to flow of a liquid due to internal friction of one part of a fluid moving over another [19]. This is a critical property because it affects the behavior of fuel injection. In general, higher viscosity leads to poorer fuel atomization [14]. High viscosity can cause larger droplet sizes, poorer vaporization, narrower injection spray angle, and greater in cylinder penetration of the fuel spray [20]. This can lead to overall poorer combustion, higher emissions, and increased oil dilution. The viscosity of biodiesel is typically higher than that of petroleum diesel – often by a factor of two. The viscosity of biodiesel blends increases as the blend level (B-level) increases. (The viscosity of straight vegetable oil is much higher yet, and is the main reason why such oils are unacceptable as diesel blend stocks.) It has been shown that in a light-duty, common rail injection system, higher viscosity resulted in increased delay in start of injection, reduced injection volume, and increased injection variability [15]. Viscosity is greatly affected by temperature [11,13]. Hence, many of the problems resulting from high viscosity are most noticeable under low ambient temperature and cold-start engine conditions. A recent study has shown that as temperature is reduced, the distribution of biodiesel fuel among individual injectors within an injector assembly becomes very unequal [18]. This, in turn, could lead to engine performance and emissions problems. Viscosity of individual oil molecules is known to increase with oil carbon number [22,23]. Several researchers have reported slight increases in viscosity upon changing the alcohol from methanol, to ethanol, to propanol.

Castor oil could not be used directly in diesel engines because of its high viscosity. High viscosity of pure vegetable oils would reduce the fuel atomization and increase fuel spray penetration, which would be responsible for high engine deposits and thickening of lubricating oil. The use of chemically altered or trans-esterifies vegetable oil called biodiesel does not require modification in engine or injection system or fuel lines and is directly possible in any diesel engine. Biodiesel extracted from castor oil were found to be within the ASTM specified limit. Table 2; shows that the kinematic viscosity of biodiesel extracted from castor oil was reduced from 68 Millipascal second (MPa.S) to 52mpa.s by the trans-esterification process. Therefore, the kinematic viscosity is a basic design specification for the fuel injectors used in diesel engines.

Table 2: Result of Viscosity of castor Oil

Temp. (℃)	**Viscosity of Crude Oil η(mpa.s)**	**Viscosity of Purified Oilη (mpa.s)**	**Viscosityof Transesterified Oil η (mpa.s)**	**Kinematic viscosity of transesterified oil (µ M^2/S)**
25	68	60	52	59.77
30	64	52	50	57.47
40	53	50	43	49.43
50	50	47	40	45.98
60	47	43	37	42.29
70	**44**	**41**	**34**	**38.77**
80	41	39	31	35.35
90	38	35	30	34.21
100	35	30	28	31.78

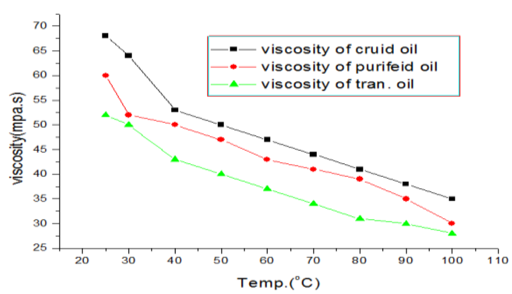

Figure 1: Graph of Viscosity of Castor oil against Temperature

From the above graph it could be seen that transestrifieds oil has low viscosity than the purified oil, crude castor oil has highest viscosity, and hence the viscosity was improving. But in all cases viscosity is decreases with increase in temperature which is the behavior of good insulating fluid. Cooling equipment in industries is mainly governed by convection, so it is necessary to have low viscosity for that application. The lower the viscosity, the better the cooling and friction reduction. Fig1; shows that the viscosity of Trans-esterified castor oil at 70ºC is 25mpa.s which is lower than the specified value 65mpa.s of standard motor oil given by Society for Automotive Engineers (SAE) at 70ºC.

The fig 2 below is the graph of dynamic and kinematic viscosities of castor oil against temperature. In both cases the viscosities decrease with increase in temperature which shows the behavior of good insulating fluid. The viscosity is the main property that plays an important role in the combustion of fuel. The direct injection in the open combustion chamber through the nozzle and pattern of fuel spray decides the ease of combustion and thermal efficiency of the engine.

Too low viscosity can lead to excessive internal pump leakage whereas system pressure reaches an unacceptable level and will affect injection during the spray atomization. The effect of viscosity is critical at low speed or light load conditions.

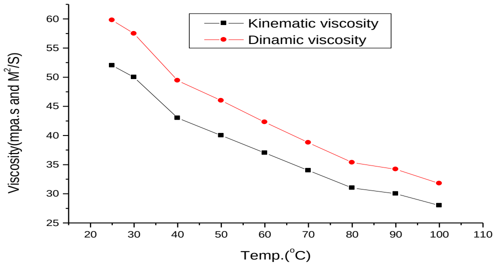

Figure 2: Graph of Dynamic and Kinematic Viscosity of Castor oil against the Temperature

FTIR spectra

The FTIR spectra shown in Figure 3, displayed the typical bands that exist in natural esters. The band with a peak at 2924 cm^{-1} describes C-H stretching. The bands with peaks at 1674 cm^{-1} and 1033 cm^{-1} are vibration of C=O and C-O.

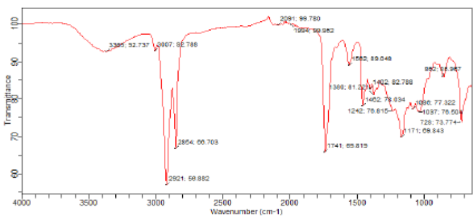

Fig 3 FT-IR Spectra of trans-esterified castor oil

Conclusion

Biodiesel was obtained from castor oil by transesterification method. The FTIR the sample confirmed that the sample is an ester which is the biodiesel. The specific gravity increase with purity and transesterification, 0.99 was obtained which is within the bounds of biodiesel standard. Also the dynamic and kinematic viscosities of the sample observed at various temperature and found out that both viscosities are decreases with increase in temperature because the increase in temperature causes the molecular or thermal energy to increase and the molecules becomes more mobile, the attractive binding energy is reduced and therefore the viscosity is reduced. The viscosity is the main factor that plays an important role in the combustion of fuel. The direct injection in the open combustion chamber through the nozzle and pattern of fuel spray decides the ease of combustion and thermal efficiency of the engine. Too low viscosity can lead to excessive internal pump leakage whereas system pressure reaches an unacceptable level and will affect injection during the spray atomization. The result obtained shows that both viscosities are decreases with increase in temperature. Therefore, the pure and transesterified castor oil can be a good lubricant due to their low viscosity.

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