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Purification and Characterization of Jatropha Biodiesel as a Fuel for Diesel Engines

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Abstract - *Diesel engine is capable of running on "biodiesel" fuel, which can be produced from a variety of renewable sources, including Jatropha seed oil. Before it can be used as a substitute for diesel fuel, the biodiesel has to undergo a purification process. The focus of this research is to investigate the purification capability of bentonite (aluminum clay), in the purification of biodiesel and the assessment of the suitability of purified biodiesel for use in diesel engines. Biodiesel was produced through homogeneous base catalysis and then purified using 5%, 10% and 15% wt/wt bentonite to oil ratio. The unpurified biodiesel batches and the purified biodiesel samples ware characterized and the properties compared with those of ASTM D6751, EN14214 and that of petroleum diesel (Australian Standard AS 3570). Some of the quality parameters were significantly affected by the adsorption characteristics of bentonite. The purification reduced the viscosity of the fuel from 5.1 c.St to a minimum value of 2.7 c.St, the bentonite was able to completely absorb the water present in the oil from a value of 0.005 %wt to completely 0.000 %wt, the calorific value was raised from a minimum value of 43125 kJ/kg to a maximum value of 44122 kJ/kg, acid value was reduced from a maximum value of 1.2 mgKOH/g to a minimum value of 0.3 mgKOH/g. All these values fall within the acceptable range of values described by the standard biodiesel properties outlined in ASTM D6751 and EN 14214. Other values like cloud point, pour point, carbon residue, copper corrosion, cetane number, peroxide value and sulphated ash were not affected by the bentonite purification. But all with the exception of sulphated ash and flash point conform to the standard biodiesel properties described by the two standards. 5% wt/wt bentonite to biodiesel ratio was able to purify the biodiesel within the acceptable values outlined in ASTM D6751 and EN 14214.*

Keywords — *Bentonite, Biodiesel, Diesel Engine, Jatropha Oil, Purification.*

I. INTRODUCTION

One of the major sources of energy in world today if fossil fuel [1]. The environmental problems associated with its use include air pollution and global warming [2]. But the limited reserves of fossil fuels are a great concern owing to fast depletion of the reserve due to worldwide increase in demand [1].

Biodiesel (mono-alkyl esters of long chain fatty acids) is a promising alternative or extender to conventional petroleum-based diesel fuel. In recent years, biodiesel has gained international attention as a source of alternative fuel due to characteristics like high degradability, no toxicity, low emission of carbon monoxide, particulate matter and unburned hydrocarbons [3 and 4]. Biodiesel also has the following advantages – it is derived from a renewable domestic resource (vegetable oil), reduces carbon dioxide emissions by 78% [5] when compared to diesel fuel on a life cycle basis, and biodegradable, making it a more environmentally friendly fuel.

Biodiesel is produced via a transesterification reaction between a vegetable oil or animal fat (which are composed of complex mixtures of triglycerides) and a low molecular weight alcohol, such as methanol. The reaction;

$$C_{57}H_{104}O_6 + 3CH_3OH \leftrightarrow 3C_{19}H_{36}O_2 + C_3H_8O_3$$ [6] ……. Eqn 1

produces a complex mixture of fatty acid methyl esters and glycerol.

The transesterification reaction can be catalyzed through a number of different methods: homogeneous alkali catalysis; homogeneous acid catalysis; supercritical alcohol with no catalyst; and via heterogeneous catalysts.

There are two kinds of catalysts typical to any biodiesel process: homogeneous and heterogeneous. Homogeneous catalysts function in the same phase (liquid, gaseous, etc.) as the reactants. Typically, homogeneous catalysts are dissolved in a solvent with the substrates. Heterogeneous catalysis is the opposite of homogeneous catalysis, meaning it occurs in a different phase than the reactants. Most heterogeneous catalysts are solids that act on substrates in a liquid or gaseous reaction mixture. Diverse mechanisms for reactions on surfaces are known, depending on how the adsorption takes place. The total surface area of solid has an important effect on the reaction rate; the smaller the catalyst particle size, the larger the surface area for a given mass of particles. However, the commercial production of biodiesel uses homogeneous catalysis process.

The homogeneous catalyst used for carrying out transesterification is usually sodium hydroxide (NaOH) or potassium hydroxide (KOH) or sodium methylate (SMO). These compounds belong to a class of materials known as bases and also are inorganic compounds, often used in organic chemistry for carrying out or catalyzing reactions. Other bases are also suitable for the transesterification reaction. The counterparts of bases are known as acids. Many acids can also be used as catalysts for transesterification. However, the base-catalyzed reaction has advantages such as a higher reaction rate [7].

Even though transesterification reaction catalyzed by alkali homogeneous catalyst such as sodium and potassium hydroxides yield higher conversion of vegetable oil to methyl esters in short time, the reaction has several drawbacks: it is energy intensive; recovery of glycerol is difficult; the catalyst has to be removed from the product; alkaline wastewater requires treatment and free fatty acids (FFA) and water interfere with the reaction [8]. The presence of water lowers the activity of catalyst, while FFA reacts with the catalyst to produce saponified product [9]. The formation of soap reduces the biodiesel yield, and causes significant difficulty in product separation and purification. Thus, biodiesel and byproduct, glycerol have to be refined by washing with hot deionized water two to three times, leading to high waste of time, energy and water [8 and 10].

Ineffective biodiesel separation and purification causes severe diesel engine problems such as plugging of filters, coking on injectors, more carbon deposits, excessive engine wear, oil ring sticking, engine knocking, and thickening and gelling of lubricating oil [11]. Several different separation and purification of biodiesel techniques have been studied.

From the foregoing, this study looks into the effect of using Bentonite (an adsorbent aluminum silicate clay formed from volcanic ash) as an adsorbent/absorbent in the purification of biodiesel produced through homogeneous catalysis.

II. MATERIALS AND METHODS

A. BIODIESEL PRODUCTION THROUGH HOMOGENEOUS CATALYSIS

Transesterification is an efficient method used for the conversion of high viscosity oil or fat into a fuel with chemical properties similar to those of conventional diesel. To obtain biodiesel, the vegetable oil or animal fat is subjected to a chemical reaction termed transesterification.

a) Preparation of Experimental Batches of Biodiesel

Transesterification reaction using homogeneous base catalysis was chosen for the purpose of this research, the oil was reacted in the presence of catalyst with an alcohol (methanol) to give the corresponding alkyl esters of the fatty acid mixture that is found in the parent vegetable oil or animal fat.

Three batches of biodiesel were produced from the raw jatropha oil.

b) Materials

The materials used for biodiesel production include;

(i) Jatropha oil
(ii) Sodium hydroxide
(iii) Methanol
(iv) Magnetic stirrer with follower
(v) Hot plate
(vi) Thermometer
(vii) Round bottom flask/ conical flask and separating funnel

c) Experimental Procedure

One liter of jatropha oil was weighed and heated to 60 ^oC in a round bottom flask. Also 1% wt/wt of NaOH was dissolved in 200 ml of Methanol to form sodium methoxide, and this was poured into the round bottom flask containing the heated Jatropha oil. The whole mixture was stirred continuously using a magnetic stirrer at 360 rpm for one hour while maintaining the temperature at 60 ^oC. After 60 min, the heating and stirring was stopped, and the mixture removed from the stirrer. The reaction mixture was transferred to a separating funnel to promote the separation of the glycerol and biodiesel phases. The glycerol phase was drained after phase separation, carrying most of the dissolved catalyst with it. The upper layer, containing the desired product (not yet purified), was also removed to a beaker and labeled Batch A.

Two additional biodiesel batches (B and C) were produced under the following conditions;

Batch B: 1.5% wt/wt of NaOH and reaction temperature of 55°C while maintaining the oil to methanol molar ratio and reaction time at 5:1 and 1 hour respectively

Batch C: 2% wt/wt of NaOH and reaction temperature of 50°C also maintaining the oil to methanol ratio and the reaction time.

B. CHARACTERIZATION OF FUEL SAMPLES

The unpurified biodiesel batches and the purified biodiesel samples (using bentonite) were characterized.

a) Unpurified Biodiesel

The three batches of the unpurified biodiesel samples were characterized using the procedures explained below, and the results were tabulated as shown in Table 1.

Determination of specific gravity: Specific gravity is the ratio of the density of a substance to the density of a standard substance at the same temperature and pressure. In the determination of specific gravity, the ASTM D-445 standard test method was used.

Determination of viscosity: Viscosity of oil is its resistance to flow. "Kinematic viscosity" measures the ease with which a fluid will flow under force. The evaluation of kinematic viscosity was carried out according to ASTM D-445. The kinematic viscosity of the samples were determined at 40 °C.

Determination of cloud point: Cloud Point refers to the temperature below which wax in diesel or biowax in biodiesels form a cloudy appearance. Cloud point indicates the tendency of the oil to plug filters or small orifices at cold operating temperatures. In crude or heavy oils, cloud point is synonymous with wax appearance temperature (WAT) and wax precipitation temperature (WPT). The test was conducted in accordance with ASTM D-2500.

Determination of pour point: The pour point of a liquid is the temperature at which it becomes semi solid and loses its flow characteristics. In crude oil a high pour point is generally associated with a high paraffin content, typically found in crude deriving from a larger proportion of plant material. It was determined in accordance with ASTM D-97 standard.

Determination of carbon residue: Carbon residue can be defined as the amount left after evaporation and pyrolysis of oil, indicating its relative propensity to form coke. It is a potential indicator of the likelihood that a fuel would form deposits from carbon in an engine's combustion chamber. The carbon residue was determined by ramsbottom carbon residue method. Carbon residue was determined using ASTM D-524 test method.

Determination of water content: This test method covers the determination of the volume of free water and sediment in middle distillate fuels having viscosities at 40 °C (104 °F) in the range of 1.0 to 4.1 mm^2/s (1.0 to 4.1 cSt) and densities in the range of 770 to 900 kg/m^3. ASTM D-2709 test procedure was used in order to determine the water content of the biodiesel.

Determination of copper strip corrosion: This test gives an indication of the corrosiveness of the fuel to the metallic parts of the system in which the product is used, whether during transportation or actual use in the engine. This property was determined using ASTM D-130 test procedure. It was determined by copper strip tarnish test.

Determination of flash point: Fuel flashpoints are measured with ASTM D-93. The flash point is the lowest temperature at which a combustible mixture can be formed above the liquid fuel. It is dependent on both the lean flammability limit of the fuel as well as the vapor pressure of the fuel constituents.

Determination of cetane number: Cetane number or CN is an inverse function of a fuel's ignition delay, and the time period between the start of injection and the first identifiable pressure increase during combustion of the fuel. In short, the higher the Cetane number the more easily the fuel will combust in a compression setting (such as a diesel engine).

In Europe, diesel cetane numbers were set at a minimum of 38 in 1994 and 40 in 2000. The current standard for diesel sold in European Union, Iceland, Norway and Switzerland is set in EN 590, with a minimum cetane index of 46 and a maximum cetane number of 51. Premium diesel fuel can have a cetane number as high as 60.

In North America, most states adopt ASTM D-975 as their diesel fuel standard and the minimum cetane number is set at 40, with typical values in the 42-45 range.

Determination of calorific value: Net Heat of Combustion (Calorific Value): The heat of combustion of a fuel at constant pressure is the number of heat units measured as being liberated at 25 °C when unit weight of fuel is burnt in oxygen at constant pressure such that the heat released is equal to the gross heat of combustion of the fuel at constant pressure less the latent heat of evaporation at 25 °C and constant pressure of the water both originally contained in the fuel and formed by its combustion. In this experiment the bomb calorimeter was used to determine the calorific values of liquid fuels (Diesel, Jatropha bio-diesel and their Blend).

Determination of peroxide value: The peroxide value is defined as the amount of peroxide oxygen per 1 kilogram of fat or oil. Detection of peroxide gives the initial evidence of rancidity in unsaturated fats and oils. Other methods are available, but peroxide value is the most widely used. It gives a measure of the extent to which an oil sample has undergone primary oxidation, extent of secondary oxidation may be determined from p-anisidine test.

Determination of free fatty acid (FFA) value: The free fatty acid was determined by calculation as shown below;

$$\boldsymbol{FFA}(\%) = \frac{\boldsymbol{Acid\ value}}{\boldsymbol{2}} \quad \text{..................Eqn 2}$$

Determination of acid value: The acid number is a measure of the amount of carboxylic acid groups in a chemical compound, such as a fatty acid, or in a mixture of compounds. In a typical procedure, a known amount of sample dissolved in organic solvent (often isopropanol), is titrated with a solution of potassium hydroxide (KOH) with known concentration and with phenolphthalein as a color indicator. It is calculated using the standard test method ASTM D-664.

Determination of sulphated ash: Sulphated ash is a measure of the residue from fuel/lubricants. It is determined by ASTM D-874 test method. The sulphated ash is the residue remaining after the sample has been carbonized, then treated with sulphuric acid and heated to constant weight. It is typically used to indicate the concentration of known metal-containing additives in new oil, including barium, calcium, magnesium, zinc, potassium and tin.

b) Bentonite Purified Biodiesel

The Nine samples of the purified biodiesel obtained from the three batches of biodiesel were also characterized using the same procedure as explained above, and the results presented in Tables 2, 3 and 4.

III. RESULTS

A. Physical and Chemical Properties of Jatropha Oil Methyl Esters (Raw Biodiesel)

The results for the physio-chemical properties of each batch are shown in Table 1 below.

Table 1: Physio-chemical properties of Jatropha oil in comparison with the produced biodiesel.

Property	**Unit**	**Test Method**	**Jatropha Oil**	**Batch A**	**Batch B**	**Batch C**
Density at 15°C	kg/m^3	ASTM D-1298	862	862	861.1	862.4
Specific Gravity	-	ASTM D-445	0.8620	0.8620	0.8611	0.8624
Viscosity @ 40°C	mm^2/s or c.St	ASTM D-445	9.5	5.1	4.9	4.5
Cloud Point	°C	ASTM D-2500	7	5	5	5
Pour Point	°C	ASTM D-97	-4	-4	-3	-4
Carbon Residue	%wt	ASTM D-524	0.051	0.042	0.039	0.040
Water Content	%wt	ASTM D-2709	0.021	0.001	0.001	0.005
Copper Corrossion	Classified	ASTM D-130	No 1A	No 1A	No 1A	No 1A
Flash Point	°C	ASTM D-93	112	104	102	103
Cetane Number	-	ASTM D-613	36	48	46	46
Calorific Value	kJ/kg	-	39133	43125	44100	44128
Peroxide Value	meq/kg	AOAC 956.3	4	5	5	5
FFA Value	-	-	1.6	0.6	0.45	0.5
Acid value	mgKOH/g	ASTM D-664	3.2	1.2	0.9	1.0
Sulphated Ash	%wt	ASTM D-874	0.087	0.067	0.043	0.050

a) Physical and Chemical Properties of Samples of the Purified Biodiesel

Tables 2, 3 and 4 shows the properties of the purified samples of which are compared with the acceptable standard properties of ASTM D-6751 and EN-14214 standards.

Table 2: Properties of purified biodiesel from Batch A

Property	**Unit**	**Test Method**	**Batch B**	**B1 5% wt/wt**	**B2 10 % wt/wt**	**B3 15 % wt/wt**	**ASTM D6751**	**EN 14214**	**AS-3570**
Density at 15°C	kg/m^3	ASTM D-1298	861.1	861.1	861.1	861.1	875-900	860-900	820-870
Specific Gravity	-	ASTM D-445	0.8611	0.8611	0.8611	0.8611	-	-	0.82 - 0.87
Viscosity @ 40°C	mm^2/s or c. St	ASTM D-445	4.9	3.0	2.9	2.9	1.9-6.0	3.5-5.0	1.9-5.5
Cloud Point	°C	ASTM D-2500	5	5	5	5			-3 to 15
Pour Point	°C	ASTM D-97	-3	-3	-3	-3	-		
Carbon Residue	% wt	ASTM D-524	0.039	0.030	0.030	0.030	-	<0.3	<0.2
Water Content	% wt	ASTM D-2709	0.001	0.000	0.000	0.000	<0.03	<0.05	<0.05
Copper Corrossion	Classified	ASTM D-130	No 1A	No 1A	No 1A	No 1A	No 1 max		No 2 max
Flash Point	°C	ASTM D-93	102	103	102	103	>130	>120	64(min)
Cetane Number	-	ASTM D-613	46	46	47	47			45(min)
Calorific Value	kJ/kg	-	44100	44119	44119	44121			
Peroxide Value	meq/kg	AOAC 956.3	5	5	5	5			
FFA Value	-	-	0.45	0.4	0.4	0.35			
Acid value	mgKOH/g	ASTM D-664	0.9	0.8	0.8	0.7	<0.8	<0.05	
Sulphated Ash	% wt	ASTM D-874	0.043	0.043	0.043	0.043	<0.02	<0.02	<0.01

Table 3: : Properties of purified biodiesel from Batch B

Property	**Unit**	**Test Method**	**Batch C**	**C1 5% wt/wt**	**C2 10% wt/wt**	**C3 15% wt/wt**	**ASTM D6751**	**EN 14214**	**AS-3570**
Density at 15°C	kg/m^3	ASTM D-1298	862.4	862.4	862.4	862.4	875-900	860-900	820-870
Specific Gravity	-	ASTM D-445	0.8624	0.8624	0.8624	0.8624	-	-	0.82-0.87
Viscosity @ 40°C	mm^2/s or c.St	ASTM D-445	4.5	3.0	3.0	3.0	1.9-6.0	3.5-5.0	1.9-5.5
Cloud Point	°C	ASTM D-2500	5	5	5	5			-3 to 15
Pour Point	°C	ASTM D-97	-4	-3	-4	-4	-		
Carbon Residue	%wt	ASTM D-524	0.040	0.041	0.039	0.040	-	<0.3	<0.2
Water Content	%wt	ASTM D-2709	0.005	0.000	0.000	0.000	<0.03	<0.05	<0.05
Copper Corrossion	Classified	ASTM D-130	No 1A	No 1A	No 1A	No 1A	No 1 max		No 2 max
Flash Point	°C	ASTM D-93	103	102	103	103	>130	>120	64(min)
Cetane Number	-	ASTM D-613	46	47	46	46			45(min)
Calorific Value	kJ/kg	-	44128	44120	44122	44120			
Peroxide Value	meq/kg	AOAC 956.3	5	5	5	5			
FFA Value	-	-	0.5	0.35	0.35	0.4			
Acid value	mgKOH/g	ASTM D-664	1.0	0.7	0.7	0.8	<0.8	<0.05	
Sulphated Ash	%wt	ASTM D-874	0.050	0.051	0.050	0.050	<0.02	<0.02	<0.01

Table 4: Properties of purified biodiesel from Batch C

Property	**Unit**	**Test Method**	**Batch C**	**C1 5% wt/wt**	**C2 10% wt/wt**	**C3 15% wt/wt**	**ASTM D6751**	**EN 14214**	**AS-3570**
Density at 15°C	kg/m^3	ASTM D-1298	862.4	862.4	862.4	862.4	875-900	860-900	820-870
Specific Gravity	-	ASTM D-445	0.8624	0.8624	0.8624	0.8624	-	-	0.82-0.87
Viscosity @ 40°C	mm^2/s or c.St	ASTM D-445	4.5	3.0	3.0	3.0	1.9-6.0	3.5-5.0	1.9-5.5
Cloud Point	°C	ASTM D-2500	5	5	5	5			-3 to 15
Pour Point	°C	ASTM D-97	-4	-3	-4	-4	-		
Carbon Residue	%wt	ASTM D-524	0.040	0.041	0.039	0.040	-	<0.3	<0.2
Water	%wt	ASTM D-	0.005	0.000	0.000	0.000	<0.03	<0.05	<0.05

Content		2709							
Copper Corrossion	Classified	ASTM D-130	No 1A	No 1A	No 1A	No 1A	No 1 max		No 2 max
Flash Point	°C	ASTM D-93	103	102	103	103	>130	>120	64(min)
Cetane Number	-	ASTM D-613	46	47	46	46			45(min)
Calorific Value	kJ/kg	-	44128	44120	44122	44120			
Peroxide Value	meq/kg	AOAC 956.3	5	5	5	5			
FFA Value	-	-	0.5	0.35	0.35	0.4			
Acid value	mgKOH/g	ASTM D-664	1.0	0.7	0.7	0.8	<0.8	<0.05	
Sulphated Ash	%wt	ASTM D-874	0.050	0.051	0.050	0.050	<0.02	<0.02	<0.01

IV. DISCUSSION

Transesterification reaction using NaOH catalyst was carried out to convert the complex esters (triglycerides) of the Jatropha oil into glycerides (biodiesel), because alkali-catalyzed transesterification reaction is the most economically viable process of producing biodiesel. Alkali-catalyzed transesterification was directly carried out (without any pre-treatment of the oil) because it was found to have little water content as well as low free fatty acid value.

The reaction converted the triglycerides into glycerides thereby reducing the viscosity of the oil from 9.5 c.St to a minimum of 4.5 c.St. The catalyst in the reaction was able to absorb some water from the oil thereby reducing the water content from 0.021 %wt to a minimum of 0.001 %wt. It also reduced the acid value from a maximum value of 3.2 mgKOH/g to a minimum of 0.9 mgKOH/g, because the alcohol in the reaction will react with the acid and reduce its value.

After the transesterification reaction, the methyl ester contains some impurities such as di- and monoglycerides, water, carbon residue and sulphated ash which needs to be maintained within some certain acceptable values, so as to prevent problems such as corrosion of engine parts and/or engine knock. A reasonable percentage of weight of bentonite (5%, 10% and 15% wt/wt) to the oil was used in the purification process to investigate the level of affinity for polar compounds by the bentonite.

The quality parameters of fuels which include viscosity, pour point, flash point, cetane number, calorific value e.t.c were investigated using the standard test methods and the values compared with those of standard properties of biodiesel as described by ASTM D6751 and EN 14214. The values are also compared with petroleum diesel properties as described by the Australian Standard AS-3570 for Automotive Diesel.

The results obtained are presented in tables 2, 3 and 4. The most important fuel parameters are thereby inspected and discussed accordingly, their values also compared with the standard.

Viscosity – a measure of a fluid's resistance to flow. It can be deduced that the lesser the viscosity of a fluid, the better it is to be used as a fuel. The viscosity of the three biodiesel samples ranges between 4.5 to 5.1 c.St, but after the purification of the biodiesel batches, the viscosity reduced to a value between 2.7 and 3.0 c.St. This shows a greater affinity of bentonite to polar compounds such as excess methanol, free glycerol and metal contaminants. The values of the viscosity obtained for all the samples are within the range of values specified by the three standards.

Cloud point - refers to the temperature below which wax in diesel or biowax in biodiesels form a cloudy appearance. Cloud point indicates the tendency of the oil to plug filters or small orifices at cold operating temperatures. Cloud point can best be characterized depending on the climate regions. The cloud point temperatures of the three batches of biodiesel (obtained as 5 °C) were not affected by the bentonite purification, because the density of the fuel remained unchanged during the process. The cloud point temperature obtained falls within the accepted value.

Pour point – the temperature at which the fuel becomes semi solid and losses its flow characteristics. Depending on the climate region, the lesser the pour point temperature the better the characteristics of that fuel. The pour point was not affected by the purification using bentonite as catalyst, as the temperature still remains -4 °C, as the density of the fuel still remained unchanged, and it is said to fall within the accepted value.

Carbon residue - the amount of carbon left after evaporation and pyrolysis of oil, indicating its relative propensity to form coke. It is a potential indicator of the likelihood that a fuel would form deposits from carbon in an engine's combustion chamber, which may cause incomplete combustion and/or engine wear if the values are above the acceptable values. After the production process, the value for the carbon residue of the first batch of biodiesel (Batch A) is 0.042 %wt and still remains the same after the purification. Same also happens to batch C, but for batch B, the value reduced from 0.039 %wt to 0.030 %wt for all the three samples of the purified biodiesel. This indicates that bentonite does not have the capability of absorbing excess carbon during the process and may lead to more carbon deposits on the cylinder head. Although not affected by the purification, the values obtained are within the acceptable range of values outlined in the standards.

Water content – amount of water present in the fuel. Appreciable amounts of water and sediment in a fuel oil tend to cause fouling of the fuel-handling facilities and to give trouble in the fuel system of a burner or engine. Water in middle distillate fuels can cause corrosion of tanks and equipment, and if detergent is present, the water can cause emulsions or a hazy appearance. Therefore, the lesser the amount of water in the fuel the better the fuel. Because of the absorption ability of the bentonite, no trace of water was observed in all the samples of the purified biodiesel. The initial values of the water content in the batches of biodiesel ranges between 0.001 and 0.005 %wt but was completely absorbed after the purification.

Flash point - the lowest temperature at which a liquid generates flammable vapours which can be ignited in air by a flame above its surface. The higher the flash point, the better will be for the fuel, because it will result to less fuel consumption and lesser deposits on the cylinder head. The bentonite did not have a significant effect on the flash point in the biodiesel batches as well as the samples of the purified biodiesel. This is as a result of uniform densities obtained by the fuel. Although the value is less than the prescribed value by the two standards of biodiesel, the value is far above that of the petroleum diesel.

Cetane number - is an inverse function of a fuel's ignition delay, and the time period between the start of injection and the first identifiable pressure increase during combustion of the fuel. In a particular diesel engine, higher cetane fuels will have shorter ignition delay periods than lower cetane fuels. The higher the cetane number the more easily the fuel will combust in a compression ignition setting. Minimizing the delay in the combustion results in less unburned fuel in the cylinder and less intense knock. Higher cetane fuels usually causes an engine to run more smoothly and quietly. The values of the cetane number ranges between 46 to 48 for the biodiesel batches as well as that of the purified biodiesel samples. Although the two biodiesel standards have not indicated any value for the cetane number, the value obtained is within that of the petroleum diesel.

Calorific value/heat of combustion – is the energy released as heat when a compound undergoes complete combustion with oxygen under standard conditions. This indicates that the higher calorific value of the fuel the more power will be developed by the engine. The two processes of biodiesel production and the purification results in higher calorific value of the fuel. The calorific value ranges between 43125 kJ/kg to 44128 kJ/kg for the three biodiesel batches and between 44118 kJ/kg to 44122 kJ/kg for the purified biodiesel samples.

Acid value - is a measure of the amount of carboxylic acid groups in a chemical compound, such as a fatty acid, or in a mixture of compounds. The acid value for the batches of biodiesel is between 0.9 mgKOH/g and 1.2 mgKOH/g. And it is between 0.3 mgKOH/g and 0.8 mgKOH/g. This also indicates the bentonite ability to absorb acid contained in the fuel. These values are within the acceptable values obtained in one of the biodiesel standards (ASTM D6751) but outside the acceptable values of the other standard (EN 14214).

Sulphated ash – is a measure of the residue from fuel/lubricant. It is typically used to indicate the concentration of known metal-containing additives in oil, including barium, calcium, magnesium, zinc, potassium and tin. The value for the sulphated ash ranges between 0.043 %wt and 0.067 %wt for the biodiesel batches and between 0.043 %wt and 0.067 %wt for the purified biodiesel samples. It can be observed that there is no change in the value of the sulphated ash after the purification process and the values are above the acceptable value specified by the two standards. This indicates that the bentonite was not able to absorb metal-containing additives in the oil.

Based on the values obtained and compared with the values of the standard biodiesel properties and that of the petroleum diesel, the parameters like density, viscosity, cloud point, pour point, carbon residue, water content, copper corrosion, cetane number and acid value are found to be within the range of the acceptable standard properties.

V. CONCLUSIONS

Because the fuel properties of the biodiesel batches produced through alkali-catalyzed homogeneous catalysis shows an appreciable improvement, and also its economic viability, the process serves as the best method for the production of biodiesel.

It can be concluded that 5% wt/wt of bentonite to biodiesel ratio can be used in the purification of biodiesel using bentonite as the adsorbent/absorbent.

All the samples of the biodiesel purified with bentonite were characterized and all the fuel parameters with the exception of flash point and sulphated ash are within the acceptable values of biodiesel standards as outlined by ASTM D6751 and EN14214 and also in conformity with values of the petroleum diesel as outlined by the Australian Standard AS-3570.

Conclusively, it can be obtained that Jatropha biodiesel produced through homogeneous base catalyzed transesterification reaction and purified with 5% wt/wt bentonite to biodiesel ratio can be substituted for petroleum diesel in a diesel engine, but because of higher sulphated ash content (present due to soluble metallic soap), the fuel may cause plugging of filters and generate more deposits in the engine than petroleum diesel.

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