FUEL PROPERTIES OF BIODIESEL FROM NEEM, COTTON AND JATROPHA BINARY AND MULTI-BLENDS WITH DIESEL

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ABSTRACT
The physico-chemical properties of biodiesel are its specifications that define a set of quality standards. These properties include specific gravity, acid number, viscosity, cetane number, flashpoint, pour point, cloud point, cold filter flogging point, sulphated ash, carbon residue, sulphur content, copper strip corrosion and free fatty acid among others. This research presents the results of specific gravity, acid number, sulphur content, colour index and copper strip corrosion of biodiesel from Cotton, Jatropha, Neem and their binary blends and multi-blends with diesel. The properties were tested in accordance with the ASTM standards and it was observed that, all the fuels conform to the ASTM standards for all the properties except the pure Neem biodiesel B100N whose colour is slightly above the standard and the acid values that are slightly below the minimum standards which depict no harm. This implies that all the fuel samples can be used in Compression Ignition engines with the anticipation of improved quality of atomization, combustion, fuel droplets, air-fuel mixing and without fear of damages on either fuel pumps and filters or climate condition due to sulphur content of the fuel.

Key Words: *Biodiesel, Binary Blends, Multi-Blends, Specific Gravity, Copper Strip, Color Index*

1. INTRODUCTION

Energy supply to the nation must be made in a responsible and sustainable deportment, which is in an approach that not only convenes the needs of the present generation but also guarantees the future generations to meet their demand (Sambo, 2011). Unfortunately, one of the challenges facing the actualization of meeting the future generations' developmental needs is the unsympathetic effects of climate change because of the disconcert of natural balance of greenhouse gases (GHG) in the atmosphere principally, carbon dioxide. Several researches were carried out and many others are still ongoing in search for solutions to the environmental menace and socioeconomic sustainability. One of the cleanest ways of burning fossil fuels is by blending them with biofuels (NNPC, 2007). The use of biomass to obtain liquid fuels is potentially attractive due to their compatibility with the current automobiles and petrol supply chains. However, the profitability of biofuels depends heavily on the economics of the byproducts. For sometimes, the glycerol has been the valuable byproduct of the biodiesel industry (Green Building Advisor, 2014). Nigeria has joined the league of countries seeking for alternatives to fossil fuels. Biofuels have emerged as a credible alternative to blend stock for the environmentally polluting petroleum resources (Izah and Ohimain, 2013).

Over the decades, fossil fuels and other carbonizing energy sources have been used to generate power for sustainable industrial growth; for transportation, lighting, powering of heating and cooling devices and for prime moving in machining and production processes. The effects of fossil fuels to our environment particularly in climate change which is principally due to greenhouse gases discharge during the combustion of fossil fuels cannot be overemphasized.

However, research has justified the use of biodiesel and bioethanol in diesel and petrol fuels respectively to produce efficiently combustible fuels which burn in internal combustion engines with reduced carbon dioxide emissions and similar power outputs (Kaisan, 2014). According to Kaisan *et al*., (2013), the physico-chemical properties of fuel are the fuel specifications that define and set the quality standards. For biodiesel, physico-chemical properties are a set of property specifications measured by specific American Society for Testing and Material (ASTM) test methods such as ASTM D6751-15b.This specification must be met for a fatty acid ester product to carry the designation "biodiesel fuel" or "B100" or for use in blends with any petroleum-derived diesel fuel. Therefore, these properties are termed physico-chemical properties which include but not limited to: specific gravity, viscosity, flash point, calorific value, cetane number, acid value, volatility, and saponification value. A binary blend is the fuel mixture that comprises of biodiesel from one feedstock and diesel, while a multi-blend consists of biodiesel from two or more feedstocks with diesel fuel.

Density is an important parameter for diesel fuel injection system (Boz *et al.,* 2009). Specific gravity is the ratio of the density of a given volume of biodiesel to the density of an equal volume of water. Many properties such as calorific value, cetane number etc are functions of specific gravity (Boz *et al.,* 2009). Specific gravity can be used to calculate the precise volume of fuel necessary to supply an adequate combustion in an engine (Silitonga *et al.,* 2013). The effect of density on injector nozzles during engine operation is obvious and can influence the efficiency of a fuel atomization for airless combustion system. The density has some effect on the breakup of the fuel injected into the cylinder (Silitonga *et al.,* 2013).

Acid number (Acid value) is the measure of the free fatty acid content of a biodiesel (Ong *et al.,* 2013). The acid value gives an indication of quality of fatty acid in the biodiesel (Belewu *et al.,* 2010. The acid value measures that amount of unreacted acids remaining in a pure biodiesel (Boz *et al.,* 2009). A very high acid value causes damages to fuel pumps and fuel filters. Acid value defines the number of milligrams of Potassium hydroxide necessary to neutralize the free fatty acids in 1g of a sample (Boz *et al.,* 2009). It can also be defined as the measure of amount of carboxylic acid groups in a chemical compound, it is also called neutralization number and it can provide indication on the level of lubricant degradation while the fuel is in service (Atabani *et al.,* 2013).

Free fatty acid is defined as percentage of fatty acid of specified molecular weight. This is usually used to test the storage quality of an oil sample. The fatty acid is expressed as millilitre of sodium hydroxide solution of specified normality, which will neutralise the fatty acid in 100g of test oil sample. Free fatty acid is a direct function of acid value.

Sulphur content is also an important property that asserts to researchers of toxicity of biodiesel exhaust emissions. The ash content of a fuel is the measure of the amount of metal contained in in a fuel. During the combustion of a fuel, biodiesel burn with a lower smoke compared to diesel (Adebayo *et al.,* 2013), hence biodiesel reduces the exhaust emissions of Sulphuric oxides. The amount of sulphur present in diesel is usually higher than that of biodiesel, therefore, biodiesel tend to lower sulphur content when blended with diesel. Copper strip corrosion is also a vital property of biodiesel because it determines whether or not the fuel has tendency to corrode an engine. Corrosion is a chemical action that destroys the surface of a metal by oxidation alone, or in combustion with a chemical process (Boz *et al.,* 2009). Free fatty acid and some sulphur compounds that exist in biodiesel may cause corrosion. This is not a healthy scenario for compression ignition engines. Copper Strip Corrosion tests recommended for all biodiesel especially before transportation and storage (Boz *et al.,* 2013).

2. METHODOLOGY

2.1 Blending

The blending was done for each biodiesel type with the petroleum diesel alone, and that of a mixed biodiesel samples (Fractional Blends or Multi Blends) with pure petroleum diesel. Each biodiesel sample was blended with fossil diesel in a ratio of 5:95, 10:90, 15:85 and 20:80, 25:75 and 30: 70 and a pure sample of each diesel as well as a pure petro-diesel sample was kept for control purpose denoted as B5, B10, B15, B20, b25, B30, B50 and B100 for the biodiesel blends and B0 for the pure petroleum diesel respectively.

Furthermore, a mixed samples of all biodiesel with the fossil diesel was made to form fractional/multi blends with B(2:2:2), B(3:3:3), B(4:4:4) B(5:5:5) and B(10:10:10) meaning 2% of each of the 3 samples in 94% diesel, 3% of each of the 3 samples in 91% diesel, 4% of each of the 3 samples in 88% diesel, 5% of each of the 3 samples in 85% diesel and 10% of each of the 3 samples in 70 % diesel mixed together respectively. Finally, the samples of the pure petro diesel, 100% biodiesels from Cotton, Jatropha and Neem seed were kept as controlled samples labelled as B0, B100c, B100j and B100n respectively.

The binary blends of Cotton Seed alone with diesel were labelled B5c, B10c, B15c, B20c, B25c and B30c. The binary blends of Jatropha alone were labelled B5j, B10j, B15j, B20j, B25j and B30j. The binary blends of Neem seed and petro-diesel alone was labelled B5n, B10n, B15n, B20n, B25n and B30n correspondingly. Ultimately, the multi-blends of Cotton, Jatropha and Neem seed biodiesel with petro-diesel were labelled B2:2:2, B3:3:3, B4:4:4, B5:5:5 and B10:10:10 in that order. The samples were kept for further analyses.

2.2 Measurement of the specific gravity:

The specific gravity of the samples was measured at room temperature using a Fisher brand hydrometer (size 0.795-0.910, accuracy 0.001). The measurement was performed according to the method adopted by (Coronado *et al.,* 2009; Kaisan *et al,* 2013).

2.3 Acid Number and Free Fatty Acid

The acid number and the FFA of these samples were determined as follows: 0.1 mole of Sodium hydroxide, (NaOH) was poured into a burette up to 25ml level and clamped on a retort stand. 1 g each of the 28 fuel samples was put into three conical flasks; 25ml of propan-2-ol was added to the three samples. Three droplets of phenolphthalein indicator were added to each of the mixtures. The 0.1 mole NaOH was titrated against the samples and the titre values were recorded (end points of the titration). The process was repeated for all the fuel samples (three different times) to get an acceptable FFA value.

The acid value was calculated from the equation below as stated by Ved and Padam, (2013):

$$Acid\ Value = \frac{5.61\ X\ T}{W} \qquad (1)$$

where: $T =$

$Volume\ in\ ml\ of\ 0.5N\ NaOH\ required\ for\ titration$

$W = Weight\ in\ g\ for\ samle\ taken$

The FFA is half of the acid value.

2.4 Total sulphur Content:

The total sulphur content was determined using X-ray analyses of the fuel samples. This test method covers the determination of total sulphur by monochromatic wavelength-dispersive X-ray fluorescence (MWDXRF) spectrometry in single-phase biodiesel and diesel fuels.

2.5 Copper strip corrosion

A three inch copper strip was prepared by cleaning and polishing all sides so that no discoloration or blemishes were visible. The strip would then place in the test samples and held for 3 hours at 100 °C as the typical starting point. At the end of the exposure period, the copper strip was removed, wiped, cleaned and matched with coloured reproduction strips to compare the feature of the strip with the standard colour codes.

2.6 Colour Index

The colours of the fuel samples were determined using ASTM D6751-15b.Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels.

3. RESULTS

Results of Physico-Chemical Properties of Cotton, Jatropha and Neem Biodiesel are presented in Figures 3.1 to 3.12 and Tables 3.1 and 3.2 respectively for specific gravity, acid number, sulphur content, colour and copper strip corrosion of Jatropha, Neem, and Cotton biodiesel with their binary and mixed blends.

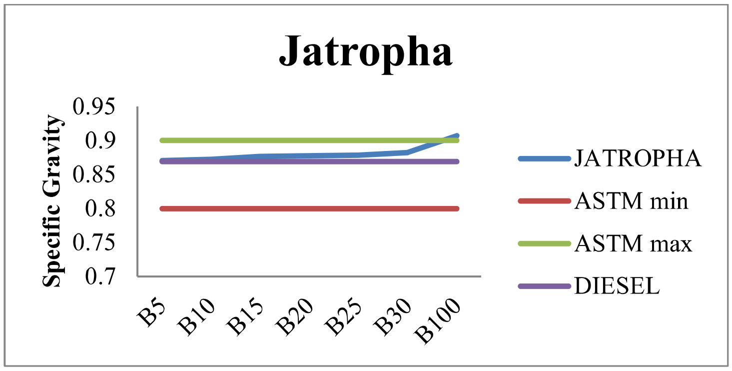

Figure 3. 1 Specific Gravity of Jatropha Biodiesel and its Binary Blends

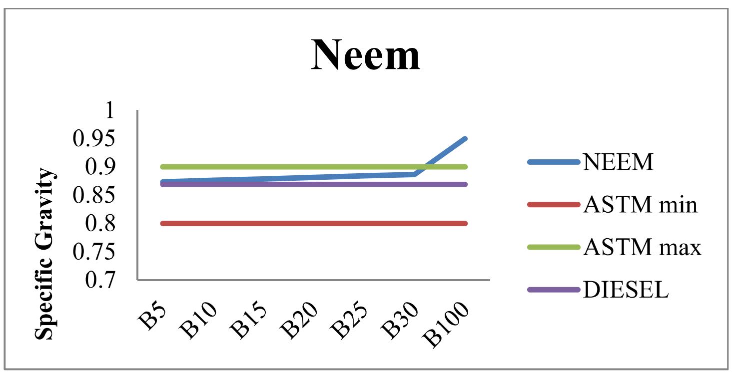

Figure 3. 2 Specific Gravity of Neem Biodiesel and its Binary Blends

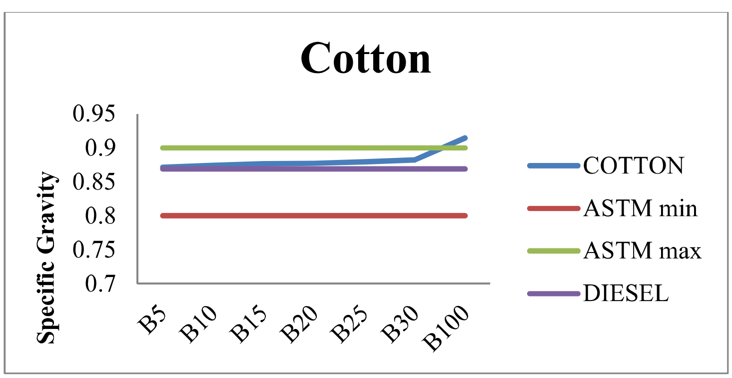

Figure 3. 3 Specific Gravity of Cotton Biodiesel and its Binary Blends

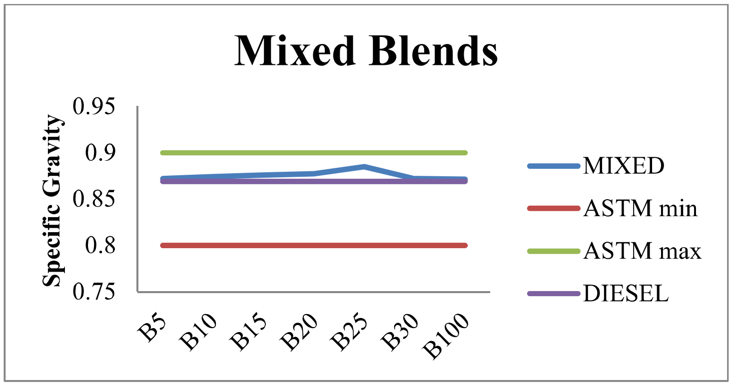

Figure 3. 4 Specific Gravity of Jatropha , Neem and Cotton Multi-Blends

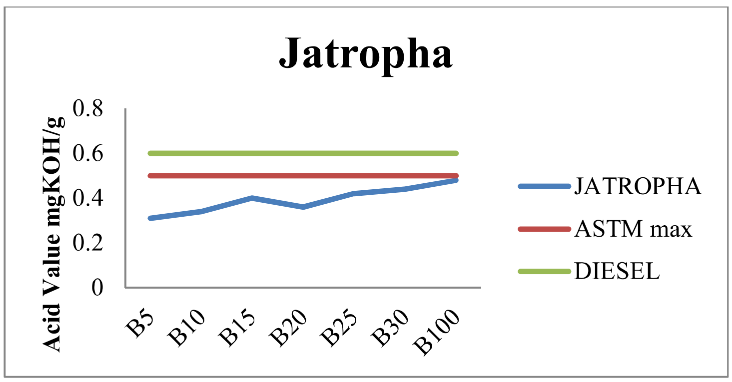

Figure 3. 5 Acid Value of Jatropha Biodiesel and its Binary Blends

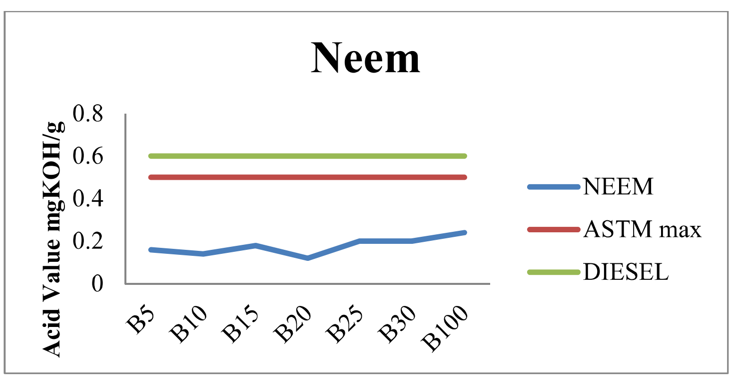

Figure 3. 6 Specific Gravity of Neem Biodiesel and its Binary Blends

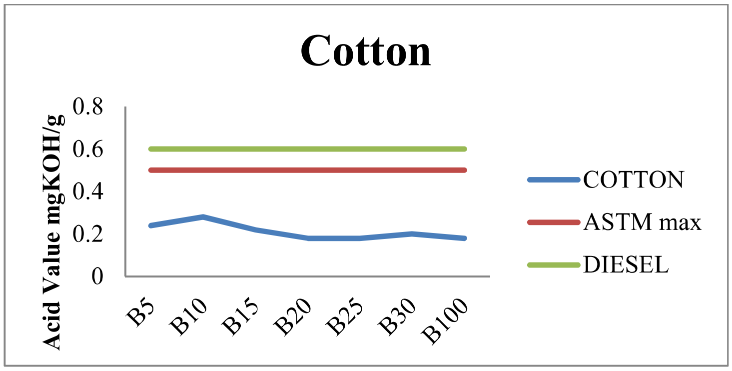

Figure 3. 7 Acid Values of Cotton Biodiesel and its Binary Blends

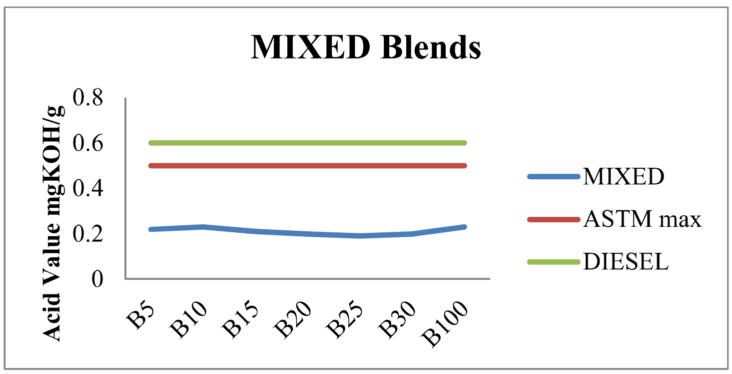

Figure 3. 8 Acid Values of Jatropha, Neem and Cotton Biodiesel Multi-Blends

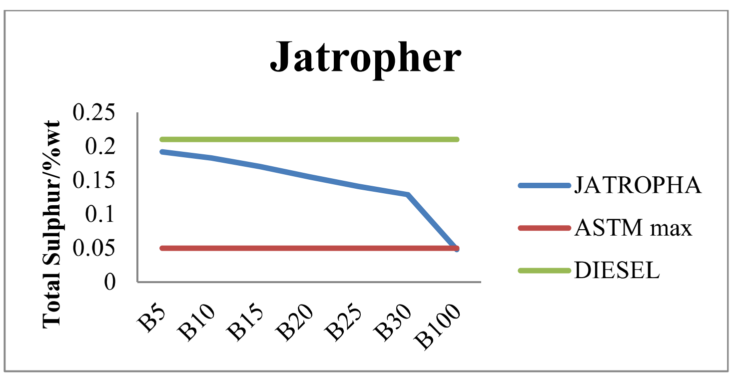

Figure 3. 9 Sulphur Content of Jatropha Biodiesel and its Binary Blends

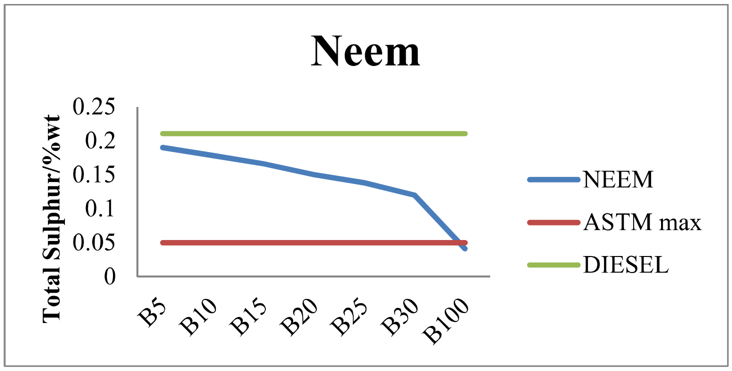

Figure 3. 10 Sulphur Content of Neem Biodiesel and its Binary Blends

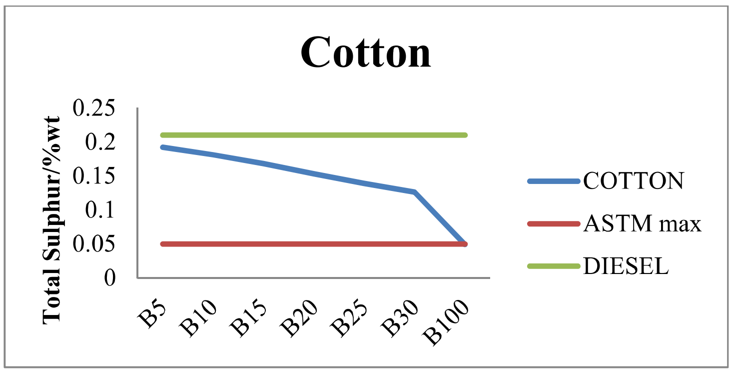

Figure 3. 11 Sulphur Content of Cotton Biodiesel and its Binary Blends

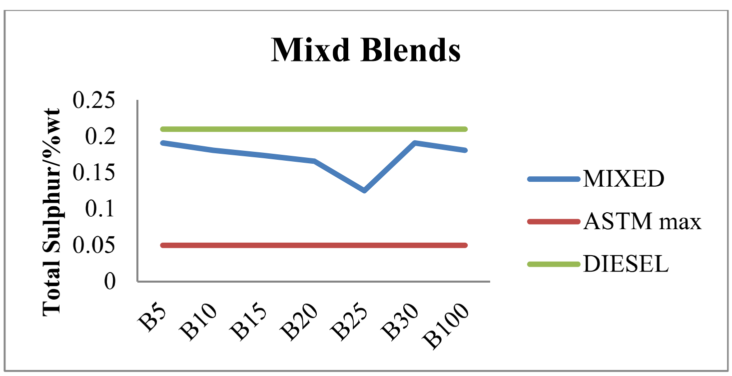

Figure 3. 12 Sulphur Content of Jatropha, Neem and Cotton Biodiesel Multi-Blends

Table3. 1 Copper Strip Corrosion of Binary and Multi-Blends of Jatropha, Neem and Cotton Biodiesel

	Copper Strip						
	B5	B10	B15	B20	B25	B30	B100
JATROPHA	1a	1a	1a	1a	1a	1a	1a
NEEM	1a	1a	1a	1a	1a	1a	1a
COTTON	1a	1a	1a	1a	1a	1a	1a
MIXED	1a	1a	1a	1a	1a	1a	1a
ASTM min	1a	1a	1a	1a	1a	1a	1a
ASTM max	3b	3b	3b	3b	3b	3b	3b
DIESEL	1a	1a	1a	1a	1a	1a	1a

Table 3. 2 Colour Index of Binary and Multi-Blends of Jatropha, Neem and Cotton Biodiesel

	Colour						
	B5	B10	B15	B20	B25	B30	B100
JATROPHA	2.0	2.0	<2.5	2.5	2.5	2.5	2.0
NEEM	2.0	2.0	<2.5	2.5	2.5	<3.0	<4.0
COTTON	2.5	2.5	<3.0	2.0	2.0	3.0	<3.0
MIXED	2.5	2.5	<3.0	2.5	2.5	2.5	2.5
ASTM min	1.0	1.0	1.0	1.0	1.0	1.0	1.0
ASTM max	3.5	3.5	3.5	3.5	3.5	3.5	3.5
DIESEL	2.0	2.0	2.0	2.0	2.0	2.0	2.0

In Figure 3.1, the result of specific gravities of Jatropha biodiesel and its binary blends were presented. Figure 3.2, 3.3 and 3.4 respectively present the specific gravities of the pure biodiesel of Neem and its binary blends, pure biodiesel from cotton and its binary blends and the multi-blends of cotton, Neem and Jatropha biodiesels. The graphs of specific gravity against the blends were depicted, in each case, the values of pure diesel and the ASTM standards maximum and minimum values were captured.

The specific gravity of Jatropha increases with increase in the percentage of biodiesel in the blends of Jatropha as it is in Figure 3.1 from B5 upto B100.

The specific gravity is an important property of biodiesel (Sivarimakrishnan and Ravikumar, 2012). It is the relative density of the biodiesel to that of an equal volume of water. The density of a fuel directly affects fuel performance, as some important fuel properties like viscosity, calorific value and cetane number are directly related to its density (Enwarenmadu *et al.,* 2012). The specific gravity of a fuel has effects on the gravity of atomization and combustion. The density and specific gravity of a fuel as well as the surface tension slightly affect fuel droplet size and air fuel mixing in an IC engine. (Hellier *et al.,* 2015). From the results presented so far, the values of specific gravity are slightly above that of diesel fuel. Hence, the quality of atomization, combustion and the fuel droplets as well as air fuel mixing can be perfectly improved by burning these biodiesel blends (binary and multi-blends of cotton, Jatropha and Neem biodiesel). This is consistent with work of Hellier *et al.,* 2015; Enwerenmadu *et al.,* (2014); Bilewu *et al.,* (2010); Tint and Mya (2009); Kalbande (2009); Reyadth (2009) and ASTM standard values.

The acid of binary and multi-blends of biodiesel from Jatropha, Neem and cotton oil with fossil diesel were depicted in figures 3.5, 3.6. 3.7 and 3.8 respectively. According to Boz *et al.,* (2009), the acid value measures the amount of unreacted acid in the finished fuel, and is always an indicator of oxidized fuel. A high acid value damages fuel pumps and fuel filters. The acid value gives an indicator of the quality of fatty acids in oil/diesel (Belewu *et al.,* 2010). Form figure 3.5, 3.6, 3.7 and 3.8, the acid value of all the blends (both binary and multi-blends) have very low acid values including those for pure biodiesel samples and fossil diesel. In fact the acid values are even lower than the ASTM minimum standards. This implies that the fuels are good to be used on CI engines without any fear of damages on fuel pumps and filters.

The total sulphur present in the fuel samples were plotted against the blends. The ASTM maximum and minimum values were also inclusive as depicted in figures 3.33, 3.34, 3.35 and 3.36. All the binary and multi-blend conform with the ASTM standards except the pure Neem biodiesel which is slightly below the minimum standard value and this means less harm. The reduction in sulphur content of the fuel reduces the tendency of emitting sulphur (IV) oxide to the atmosphere during the combustion of the diesel fuel. This leads to the avoidance of the formation of acid rain which occurs when the rain water dissolves SO_2 to form sulphuric acid. The said acid rain is one of the major causes of cancer. These results are consistent with the findings of Kaisan *et al*., (2013).

The minimum value for copper strip corrosion based on ASTM standards is 1a and the maximum is 3c. From Table 3.1 all the samples have the best copper strip value of 1a each. This is consistent with the work of Kaisan *et al*., (2013). This shows that all the fuel samples are not liable to form corrosion in CI engines. The samples are hereby suitable for CI engines operations.

Table 3.2 shows the colour indices for all the biodiesels from Jatropha, Neem, cotton and the pure diesel with their respective binary and mixed blends. The minimum ASTM colour code is 0.1 and the maximum is 3.5. From the table, all the fuel samples under investigation except the 100% Neem biodiesel have consistent colour indices. B100N has a colour index <4.0 which is not a suitable colour for biodiesel. Although this does not affect any of the performances of the biodiesel in diesel engine. This result is contrary to the findings of Kaisan *et al*., (2013) where all the colour indices are beyond the standard values prescribed by ASTM. Hence these fuels are very good to operate any CI engine.

4. CONCLUSION

The subsequent inferences were made from the discoveries of this work:

1- The specific gravity of the binary blends of cotton, Jatropha and Neem increases with the percentage increase of the biodiesel content in the blends. All the blends conform to the ASTM standards for specific gravity. The quality of atomization, combustion, fuel droplets and air-fuel mixing can be improved in CI engines by using these blends.

2- The acid values are very low and slightly lower than the ASTM minimum standards which are presumed to cause no harm on the fuel pumps and filters
3- All the 27 fuel samples and the pure diesel are consistent with the ASTM standards for total sulphur, copper strip and colour index except B100N for colour index.

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