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Fuel Quality Assessment of Biodiesel Produced from Groundnut Oil (*Arachis hypogea*) and its Blend with Petroleum Diesel

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ABSTRACT

This study was carried out to produce biodiesel from methyl esters of groundnut (*Arachis hypogea*) oil and blend with Petrol diesel. The fuel quality of the biodiesel and its blend (B10) was assessed and compared with the ASTM (American Society for Testing and Materials) standards. The groundnut oil was characterized for specific gravity, kinematic viscosity, moisture content, ash content, acid value, free fatty acid, saponification value, iodine value and peroxide value, refractive index and flash point. The biodiesel produced was analyzed for the same parameters including calorific value. The results obtained for the biodiesel showed that while the moisture and ash content were satisfactorily found in trace quantities, the other parameters also had satisfactory results within the specification of 0.88 (specific gravity), 5.16 $mm^2 sec^{-1}$ (kinematic viscosity), 4.96 mg KOH g^{-1} (acid value), 2.49% (free fatty acid), 244.74 mg KOH g^{-1} (saponification value), 52.45 mg KOH g^{-1} (iodine value), 3.23 mEq kg^{-1} (peroxide value), 1.463 (refractive index), 202°C (flash point) and 39,114.29 J g^{-1} (calorific value). However, the acid value was found to be higher than the maximum permissible level of 0.8 mg KOH g^{-1}. There was obviously very little change in the parameters of the biodiesel when it was blended except for the flash point which was only slightly below the recommended minimum ASTM value of 130°C. This indicates that the biodiesel produced could be blended with petrodiesel (B10) to give satisfactory fuel with properties not too different from the biodiesel produced.

Key words: Biodiesel, petrol diesel, methyl esters, fuel quality, groundnut oil, ASTM standards

INTRODUCTION

Energy is a fundamental requirement for human existence. Many countries in the world are resorting to biofuel technology to solve the problem of the gradual increasing rate of fuel and energy prices resulting from the depletion of the world's non-renewable fossil fuels. This has led to research into alternative fuels to replace conventional petroleum fuel of which biodiesel is one of them. Biodiesel is a renewable energy source which can be produced from vegetable oils and animal fats. Biodiesel as an alternative fuel has numerous advantages over conventional fossil fuels such as, biodegradability, renewability, high combustion efficiency, low sulfur and aromatic content (Shahbaz *et al*., 2010). It also has low idle noise and easy cold starting. Its addition reduces engine wear thereby increasing the life of the fuel injection equipment (Emil *et al*., 2009). It has been shown to have high lubricity than any other fuels (El-Diwani and El-Rafie, 2008). It also improves the quality of the environment with a pleasant fruity odour and with less soot generated in the exhaust of the vehicle. It actually produces less particulates, having higher cetane numbers and producing lower carbon monoxide and hydrocarbon emissions (El-Diwani *et al.*, 2009).

Certain edible oils such as cottonseed and safflower can be used as raw materials for biodiesel production. Some of the non-edible oils such as mahua, castor, neem (*Azadiracta indica*), rice bran, linseed, Karanja (*Pongamia pinnata*), jatropha (*Jatropha curcas*) etc. can also be used. The raw material being exploited commercially by the developed countries constitutes the edible fatty acid oils derived from rapeseed, soyabean, palm, sunflower, coconut and linseed (Korbitz, 1999). However, availability of these raw materials varies. Groundnut is mainly grown in the northern part of Nigeria and the oil is readily available in all parts of Nigeria in large quantities. Although an edible oil, its use as a potential feedstock for biodiesel production may not likely compete with peanuts grown for food and commercial cooking oil products. This is because it has been reported that Nigeria possesses land area of 923,768 km^2 arable land constituting about 56% and vegetation ranging from the Sahel savanna in the extreme North to swamp forest in the south (Sambo, 2007). Therefore most parts of Nigeria are suitable for biofuel crop cultivation including groundnut oil (Ofoefule *et al.*, 2008). This strategy is effectively being employed in USA and Brazil as they are world largest producers of bioethanol from Sugarcane and other raw materials (Ibeto *et al.*, 2010). Some studies have been carried out on biodiesel production of different oils. Methyl esters of soybean oil, canola oil, palm oil, waste cooling oil and coconut oil (Coronado *et al.*, 2009) sunflower oil (Arzamendi *et al.*, 2008) and palm oil (Baroutian *et al.*, 2008) have been determined. However, the major problem of biodiesel is it's cold flow properties which is represented by the pour point. The pour point is the lowest temperature at which frozen oil can flow and is often used to specify the cold temperature usability of fuel oil (Encinar *et al.*, 2007). Neat biodiesel has a pour point of 3°C (Peterson *et al.*, 1990). In colder climates, crystallization can occur which leads to the plugging of fuel lines. Typically taking U.S as a case study, biodiesel is mostly blended with diesel fuel. Such a blend would have better cold flow properties compared to neat biodiesel (Alamu *et al.*, 2010). This study was carried out to assess the fuel quality of biodiesel produced from methyl esters of groundnut oil (*Arachis hypogea*) and its blend with Petrol diesel when compared with the ASTM (American Society for Testing and Materials) standards.

MATERIALS AND METHODS

The groundnut oil was purchased from the local market. Analytical grade reagents were used for all the analyses carried out without further purification. The Methanol used was a product of Merck, Darmstadt, Germany (99.7% purity) while the sodium hydroxide was a product of Loba Chemie GmbH Switzerland (85% purity). Other materials also used were specific gravity bottle, oven (BTOV 1423), Vecstar furnace LF3, Ferranti portable viscometer model VL, Abbe refractometer, semi automatic Cleveland flash point tester and Hewlett Adiabatic Bomb Calorimeter model 1242. This study was carried out in the National Centre for Energy Research and Development, University of Nigeria Nsukka in August, 2010.

The oil was characterized for the specific gravity using a specific gravity bottle, moisture content by the oven dry method, ash content by heating to dryness in furnace, kinematic viscosity using a viscometer, the acid value, saponification value, Iodine value and Peroxide value by titrimetry, refractive index using Abbe refractometer and flash point using the semi automatic Cleveland flash point tester (Van Gerpen, 2005). Percentage free fatty acid (% FFA) (as oleic) was determined by multiplying the acid value with the factor 0.503. Thus % FFA = 0.503×acid value (Akubugwo *et al*., 2008).

Preparation of potassium methoxide: Thirty millilitre of methanol was measured into a 250 mL flat bottom flask and covered immediately. 1.06 g of potassium hydroxide was carefully added into the methanol to make a solution which was made airtight. It was shaken and swirled for a few times until the KOH was completely dissolved.

Biodiesel production and purification: The transesterification reaction was carried out in a 500 mL airtight flat bottom flask containing a magnetic stirrer. The 100 mL of the groundnut oil was measured into the flask and was heated to a temperature of 55°C. The potassium methoxide was then poured into the flask containing the oil and was immediately covered. The temperature of the system was maintained between 60-65°C throughout the one hour reaction time. At the end of the reaction, the mixture was transferred into a seperatory funnel, left for 24 h and then the biodiesel separated from the glycerol. The biodiesel was then washed with warm water five times to a neutral pH to remove the glycerol, catalyst and other impurities (Alamu *et al*., 2007; Chitra *et al*., 2005). While the glycerol was not refined further but was kept for other uses.

The biodiesel and it's blend (B10) were analysed in the same way as the groundnut oil for the same parameters except for calorific value using a Bomb Calorimeter (Van Gerpen *et al*., 2004).

RESULTS AND DISCUSSION

As shown in Table 1, the biodiesel yield from groundnut oil was 79%. This was lower than 88% reported by Galadima *et al*. (2008). The groundnut oil used for this study was obtained commercially and may contain additives such as vitamins which may have affected the yield. However, the yield was higher than that obtained by Itodo *et al*. (2009) in the comparative study on biodiesel yield of soy and groundnut oils. This was attributed to low conversion efficiency of the transesterification process resulting from inappropriate free fatty acid and moisture contents of the oil. The moisture content of the groundnut oil was 0.09% which was lower than 0.1% obtained by Itodo *et al*. (2009). As shown in Table 2, the moisture content of the biodiesel and its blend (B10) was trace which is found to be within the ASTM (American Society for Testing and Materials) stipulated maximum value of 0.05% (US Department of Energy, 2004).

Table 1: Quality parameters of groundnut oil

Properties	Groundnut oil
Specific gravity	0.93
Kinematic viscosity (mm^2 sec^{-1})	32.66
Moisture content (%)	0.09
Ash content	Trace
Acid value (mg KOH g^{-1})	2.61
FFA (%)	1.31
Saponification value (mg KOH g^{-1})	148.67
Iodine value (mg g^{-1})	89.46
Peroxide value (mEq kg^{-1})	22.25
Refractive index	1.463
Flash point (°C)	178.00
Biodiesel yield (%)	79.00

Table 2: Quality parameters of the biodiesel (B100) and its blend with petroleum diesel (B10)

Properties	B100	B10	ASTM standard
Specific gravity	0.88	0.85	-
Kinematic viscosity (mm^2 sec^{-1})	5.16	5.62	1.9-6.0
Moisture content (%)	Trace	Trace	0.05 max
Ash content (%)	Trace	Trace	0.02 max
Acid value (mg KOH g^{-1})	4.96	5.89	0.8 max
FFA (%)	2.49	2.96	-
Saponification value (mg KOH g^{-1})	244.74	218.09	-
Iodine value (mg KOH g^{-1})	52.45	63.77	-
Peroxide value (mEq kg^{-1})	3.23	2.17	-
Refractive index at 29°C	1.463	1.462	-
Flash point	202°C	103°C	130°C min
Calorific value (J g^{-1})	39,114.29	39,114.29	-

The specific gravity was 0.88 and 0.8571 for the biodiesel and its blend respectively which were within the standard range of 0.87-0.90 for the biodiesel and 0.81-0.86 for petrodiesel (Ejikeme *et al.*, 2008). Density and other gravities are important parameters for diesel fuel injection systems. The values must be maintained within tolerable limits to allow optimal air to fuel ratios for complete combustion. High-density biodiesel or its blend can lead to incomplete combustion and particulate matter emissions (Galadima *et al.*, 2008). The flash point for the biodiesel was well above the 130°C minimum ASTM recommended range and therefore no risk of fire outbreaks in case of accidents. However the flashpoint for the blend was 103°C which only conformed to the>100°C recommended Flash point by SNI 04 (Sulistyo *et al.*, 2008).

The acid values for the biodiesel and its blend were well above 0.26 mg KOH g^{-1} obtained by Alkabbashi *et al.* (2009) in their analysis of crude palm oil and also the ASTM recommended 0.8 max mg KOH g^{-1}. This could be attributed to the fact that the oil was used without purification even though it had additives. The kinematic viscosity of the biodiesel (5.16 mm^2 sec^{-1}) and the blend (5.62 mm^2 sec^{-1}) were within the recommended ASTM range of 1.9 to 6.0 mm^2 sec^{-1}. The iodine value of 52.45 and 63.77 mg KOH g^{-1} for the biodiesel and its blend respectively were lower than the standard iodine value for biodiesel of 120 by Europe's EN 14214 specification (Son *et al.*, 2010). The iodine value is a measure of the unsaturation of fats and oils. High iodine value indicates high unsaturation of fats and oils (Knothe, 2002). Saponification value is used in checking adulteration. Saponification value for the biodiesel was 244.74 mg KOH g^{-1} while that for jatrhopa oil seed as reported by Akbar *et al.* (2009) was 193.55 mg KOH g^{-1} and estimated to be high. High saponification value indicated that oils are normal triglycerides and very useful in production of liquid soap and shampoo industries. The high saponification values obtained indicates the presence of high percentage of fatty acids which might lead to soap formation (Oluwaniyi and Dosumu, 2009), hence the separation of products will be exceedingly difficult. This could account for the low yield of biodiesel product.

Comparing the properties of the biodiesel and its blend, there is obviously very little change in the parameters obtained from the biodiesel when it was blended. For instance, the acid value obtained for both, did not meet the ASTM standard. The only property of the biodiesel which was affected with the blending was the flash point which decreased from 202°C for the biodiesel to 103°C for the blend. This infers that biodiesel produced from groundnut oil can be conveniently blended with petrol diesel with the quality of the biodiesel still effective as an alternative fuel.

CONCLUSION

The fuel properties of groundnut biodiesel were found to be comparable to those of diesel and conformed to the ASTM standards. However, the biodiesel blended with petrodiesel (B10) gave satisfactory fuel properties not too different from the biodiesel produced. Groundnut oil is a good feedstock for biodiesel production which can be partially substituted for petro-diesel under most operating conditions, regarding performance parameters without any modifications having to be made to the engine.

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