NIGERIA JOURNAL OF PURE AND APPLIED PHYSICS

Nigeria Journal of Pure and Applied Physics, Vol. 7, No. 1, pages 1 – 6, 2017

UTILIZATION OF SOME NON-EDIBLE OIL FOR BIODIESEL PRODUCTION

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Abstract: In this work, the production of biodiesel from four sources of non-edible oils, namely jatropha, animal fat, waste vegetable oil and castor oil was carried out. It was done using an acid esterification process followed by alkali transesterification in the laboratory. Subsequently the physicochemical properties for four blends B100, B80, B50 and B20 were determined to establish their adherence to the ASTM standard for biodiesel. The percentage yields of the biodiesel from jatropha, animal fats, waste vegetable oil and castor oil were 98, 85, 95 and 90 % respectively. Highest density value was 0.8870g/cm^3 for jatropha (B100), while lowest density of 0.8502 g/cm^3 /cm^3 was obtained from animal fats (B20). The highest value of flash point was 179^{o}C for jatropha (B100), while the lowest flash point was 102^{o}C for animal fats (B20). Viscosity values ranged from 5.254mm^2/s for animal fats (B100) to 2.891mm^2/s for castor oil (B20), the lowest pour point was -9^{o}C for castor oil (B20), while the highest pour point was 15^{o}C for animal fats (B100). All the physicochemical properties examined in this study were within the ASTM standard range apart from the flash point for animal (B20) which was below the standard range.

Keywords: non-edible oil, Jatropha, biodiesel, Alternative fuel, physio-chemical properties

1. INTRODUCTION

Energy is an integral part of human existence. Nigeria is endowed with both conventional and non-conventional energy sources in abundance. The non-conventional energy sources which are green and clean forms of energy such as hydropower, solar, wind, biomass, biodiesel, etc. are eco-friendly, non-polluting and replenishes in nature. Whereas the conventional energy sources such as nuclear energy, natural gas, coal and fossil fuel cannot be replaced in a reasonable amount of time. The use of conventional forms of energy is linked to environmental pollution and global warming which is because of gas flaring and combustion of fossil fuel [1]. Continued use of fossil fuels as a source of energy is now widely recognized as unsustainable because of its declining supplies and the contribution of these fuels to the increased carbon dioxide concentrations in the environment, which is a great concern regarding greenhouse gas emissions [2].

Biodiesel is a non-conventional energy source produced from edible oil such as soya bean oil, corn oil, groundnut oil, palm oil, and sunflower oil and non-edible oil such as animal fat, waste vegetable oil, jatropha oil, algae oil, and castor oil. It is produced through transesterification process from oil and alcohol in the presence of sodium hydroxide (NaOH) or potassium hydroxide (KOH) as a catalyst with glycerin as a by-product. Biodiesel can be used in pure or blended form to suit the compression ignition engine [3]. Ramadhas et al., [4] reported that biodiesel is a promising alternative fuel source with benefits over fossil fuel, such as biodegradability, renewability, high combustion efficiency, low sulfur and low emission. According to Hill *et al*., [5], it reduces engine wear thereby increasing the life of the fuel injection equipment and improves the quality of the environment with a pleasant fruity odour with less soot generated in the exhaust of the vehicle. Biodiesel produces less particulate materials, low idle noise and easy cold starting when in use [6]. Similarly, Demirbas [7] found that biodiesel has high lubricity than any other fuels, safer to handle being less toxic, having a higher flash point and high cetane number than diesel, and producing lower carbon monoxide and hydrocarbon emissions.

However, a huge percentage of biodiesel is being produced from edible vegetable oil, which has direct competition with food supply. Therefore, to overcome this devastating occurrence, efforts are being made to produce biodiesel from other sources of oil which are non-edible [8]. For this study, non-edible oils such as animal fat, castor oil, Jatropha and waste vegetable oil were considered for the production of biodiesel.

Waste Vegetable Oil (WVO) refers to vegetable oil that is no longer useful for food production. It can be obtained from homes, restaurants, eateries, and hotels. The growing pollution of over 160 million people in Nigeria [9] has consequentially increased the rate at which fast food companies, restaurants and hotels are being set up. The enormous volume of WVO generated from these establishments and ceremonious events on a daily basis poses a serious danger in disposing them. Improper disposal of WVO can cause environmental pollution. Since biodiesel can be produced from WVO, to a large percentage the problems related with WVO disposal can be put under control. Also, various business organizations and homes that generate WVO can sell it to biodiesel producers and make extra income. It was reported by Anh and Phan Tan [10] that, the use of waste vegetable oil as feedstock reduces biodiesel production cost by about 60–70% because the cost of feedstock constitutes approximately 70–95% of the total cost of biodiesel production.

Jatropha belongs to the family of *Euphorbiaceae*. The plant is known as *Lapalapa* in Yoruba, *Wuluidu* in Igbo and *Cini da zugu* in Hausa. The two varieties found in Nigeria are *Jatropha curcas and Jatropha glandulifera.* Also, it is a hearty multipurpose shrub-type tree, drought resistant perennial plant with a productive life of over 40 years and grows wildly in Nigeria with little or no maintenance [11]. The seed of the plant has a potential of 60% oil production within 2 to 4 months of its maturity, with an estimated yield of 3 litres of oil from 12 kg of seeds. Jatropha plants are considered as the best source of production of biodiesel among the various plants-based fuel resources all over the world [12]. Castor plant is another feedstock of interest. This plant is also from the family of *Euphorbiaceae* and botanically is known as *Ricinus communis*. The plant has various names such as castor oil plant, wonder boom, castor bean plant, E*randa*, Palma Christi and D*atura*. Castor oil is extrated from castor seed. Oplinger et al., [13] reported that the seed is made up of 35 to 60% of oil which is rich in triglycerides. The yield per hectare per year could reach up to 1000kg oil. Castor plant is a perennial crop that can be harvested within 4 to 5 months [14].

Lastly, the volume of waste generated at the slaughter houses in Nigeria is alarming, and poses a serious menace to the environment due to improper handling, thereby causing land, water and air pollutions [15, 16]. Omole and Ogbiye, [17] found that animals slaughtered at Nigerian abattoirs include cows, sheep, goat, pigs and chickens. According to Omole and Ogbiye, [17] 11% of fats is available from slaughtered cattle in the abattoir, and based on the report in the Lagos State Digest of Statistic 2011, the number of slaughtered cattle increased from 420,643 in 2009 to 433,457 in 2010. Hence, research on ways to re-use these animal parts is needful. This is essence of this study so as to help reduce the waste and increase employment opportunities.

2. MATERIALS AND METHODS

2.1 Raw materials preparation and characterization

Four types of feedstock were considered in this study. They are animal fats, WVO, castor oil and jatropha oil. The animal fats of tallow were collected from an abattoir in Yaba, Lagos. The fat was melted and filtered in order to remove gums, protein residues, and suspended particles. The WVO was collected from a local restaurant in Lagos, and then filtered to remove impurities. The castor oil was purchased as 100% refined oil at OBA market, Mushin, Lagos. The crude jatropha oil was bought at Oshodi market in Lagos. Analytical grade methanol of 99.8% purity and Merck potassium hydroxide pellets of pure grade obtained from the Mon Scientific store, Lagos was used in this study. All other solvents used were analytical grade.

2.2 Determination of free fatty acid (FFA)

FFA concentration in fats and oils is calculated as percentage oleic acid from a titration value. The expression as given in AOCS Official Method Ca 5a-40 [18] is:

$$FFA(\%) = \left(\frac{(v-b) * N * 28.2}{w} \right) \quad (1)$$

where v, b, N and w are the volume (ml) of titration solution, volume (ml) of the blank (initial), normality of the titration solution and weight of the sample of oil (grams) respectively.

2.3 Production of biodiesel from feedstock

Due to the high FFA content of the respective feedstock, firstly the conversion of jatropha, WVO and animal fat to biodiesel was carried out by the acid esterification process, before the transesterification process. During the esterification process, 70ml of sulfuric acid as catalyst was dissolved in 40ml of methanol in a 500ml flask which contain a magnetic stirrer and then mixed with the 300ml preheated WVO, animal fat and jatropha oil separately. The mixture was heated at a controlled temperature of 55ºC and stirred constantly at 200 rpm for one hour, in order to eliminate the excess FFA content for an enhanced biodiesel yield.

The transesterification process was carried out by addition of potassium methoxide into an airtight 500ml flask containing the castor oil and the three pre-treated oil. In a molar ratio of alcohol to oil 3:1, an extra amount of alcohol is suggested in order to shift the equilibrium to the product side and increase the conversion. The temperature of the system was kept between 60-65ºC for one hour. The mixture was transferred into separating funnel and allowed to separate by gravity for 24 hours. Glycerol being heavier than biodiesel settled at the bottom of the funnel and was drained off. The biodiesel left in the funnel was washed with lukewarm water five times to a neutral pH (7) to remove the residue glycerol, catalyst and other impurities. The biodiesel was dried by adding Magnesol adsorbent and stirred for 15 minutes. The final purified biodiesel was gotten by filtration to remove the adsorbent.

2.4 Determination of physiochemical properties

The physicochemical properties were analyzed in the Petroleum Laboratory II, at the Department of Chemical Engineering, University of Lagos. The analyses were carried out using the Association of Official Analytical Chemists methods [19]. The flash point was determined by an automated Pensky-Martens closed-cup apparatus in the temperature range of 60 to 190ºC according to ASTM D93 - 11 Standard Test Methods for flash point. Viscosity was determined using Digital Viscometer SVM 3000 (Anton Paar) at 40ºC temperatures according to the ASTM D-445. The density was determined using a density bottle. Other properties analyzed were the pour point and the cloud point according to ASTM D6371 - 05 Standard Test Method for Heating and Cold Filter Plugging Point of Diesel Fuels. Acid value was calculated by using the formula 2 x FFA% [19].

3. RESULTS AND DISCUSSION

The results obtained for the biodiesel percentage yield and some physicochemical properties of the biodiesel and three other blends which are B80, B50, and B20 are reported below as follows:

Table 1 shows the values of percentage free fatty acid (FFA) to be 0.10 for animal fat which has the highest FFA content while Jatropha oil has the lowest FFA of 0.06. The volume of the feedstock used which is referred to as feedstock input was 300mL. The transesterification process was carried out under the same conditions; however, the percentage biodiesel yield was different as jatropha oil gave the highest yield of 98%, followed by 95% of WVO. The lowest yield 85% was gotten from animal fat. Accordingly, their acid value followed with the highest value of 0.12 mgKOH/g from Jatropha and lowest value of 0.20 mgKOH/g from animal fat.

Figure 1 is an illustration of Table 2 in a chart format showing the biodiesel percentage yield from various feedstocks, their acid value and the percentage free fatty acid content (%FFA). According to Highina *et al.*, [20] the percentage yield of biodiesel from Jatropha curcas oil was 97%; a little lower than was obtained in this study. The higher yield is related to the low FFA due to the esterification process and subsequent low acid value. Thus, the lower the FFA the higher the percentage yield and the lower the acid value. Adepoju and Olawale, [21] in their work obtained 95.6% yield from WVO; Carmen, [22] obtained 80-82% yield from castor oil and Hoque *et al.*, [23] got 87.4% yield from animal fat. These values are satisfactory and in agreement with the report by Aransiola *et al.*, [24] that jatropha curcas oil with FFA level less than 1% will give a high yield of biodiesel.

Table 1: Percentage yield of biodiesel production

S/N	Feedstock	FFA (%)	Feedstock input (ml)	Feedstock output (ml)	Yield (%)	Acid Value*
1	Animal fat	0.10	300	255	85	0.20
2	WVO	0.07	300	285	95	0.14
3	Jatropha oil	0.06	300	294	98	0.12
4	Castor oil	0.08	300	270	90	0.16

*Acid Value: %FFA*2(mgKOG/g)

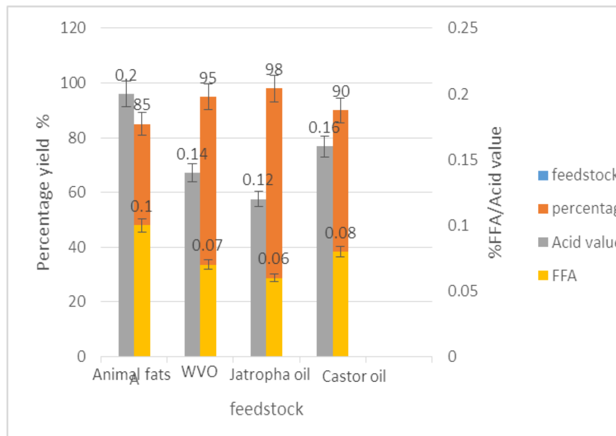

Fig. 1. A chart of biodiesel percentage yield, FFA and acid value

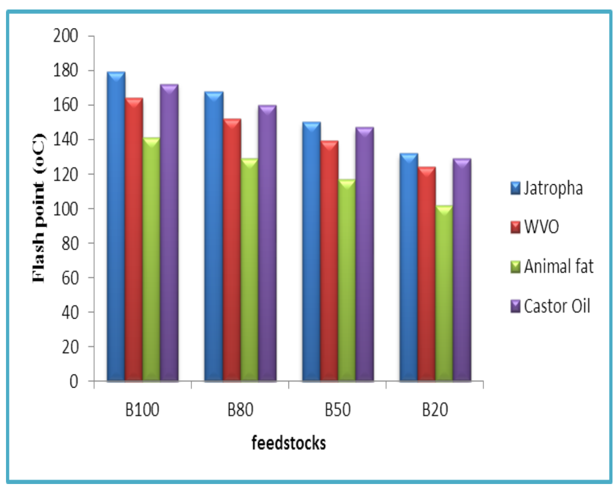

Fig. 2. Variation of Flash point for different feedstocks

A chart of flash point of various blends of biodiesel is shown in Fig. 2. For the 100 percent biodiesel B100 Jatropha oil has the highest flash point value of 179ºC, while animal fat has the lowest value of 141ºC. The same also applied for the other blends B80, B50 and B20 Jatropha has the highest flash point values while animal fat has the lowest flash point values. The values of the flash

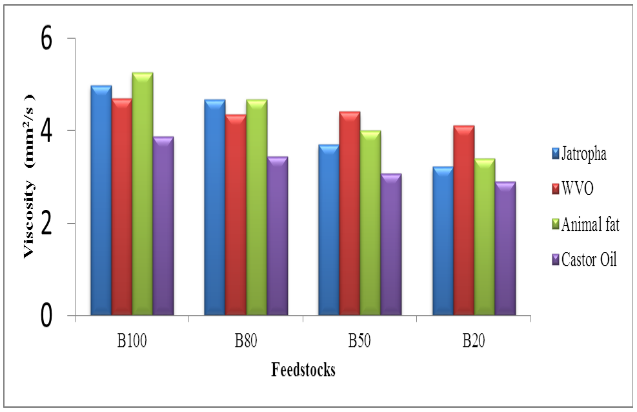

Fig. 3: Variation of Viscosity for different feedstocks

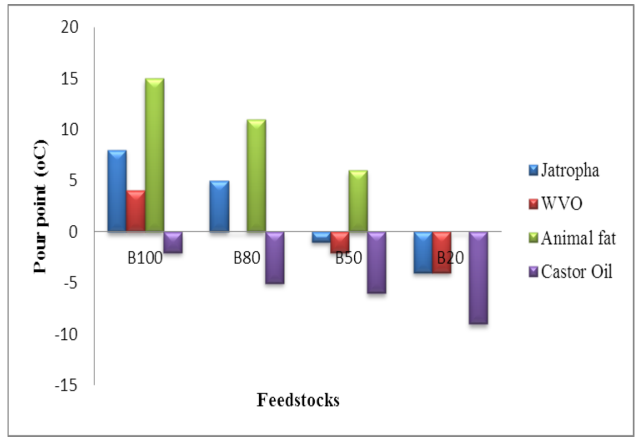

Fig. 6: Variation of Pour point for different feedstocks

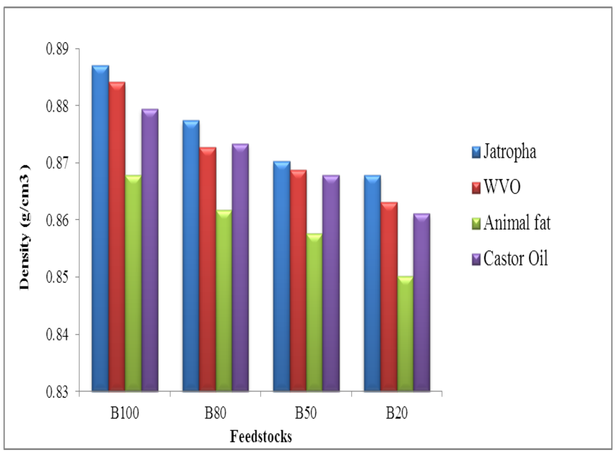

Fig. 4: Variation of Density for different feedstocks

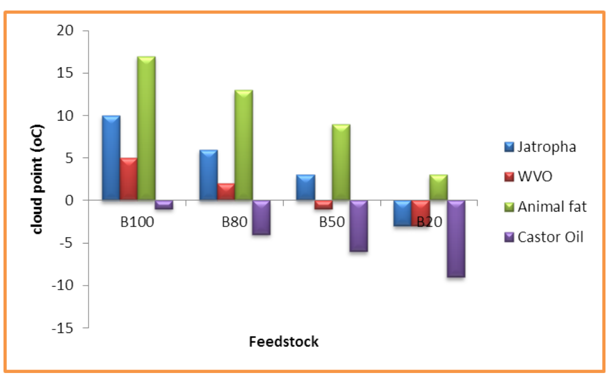

Fig. 5: Variation of Cloud point for different feedstocks

point obtained for both pure biodiesel B100 and the blends for the four types of feedstock were all within the ASTM recommended range (100-170ºC), which implies that they pose no risk of fire outbreaks in the case of accidents. Hence, biodiesel and its blends are safe during transportation, handling and storage. However, blends lower than B20 will have the tendency to reduce the flash point below the ASTM standard range as seen with B20 of animal fat.

The values of the viscosities obtained are shown in Figure 3. The highest viscosity value 5.254mm^2/s was gotten from animal fat, followed by 4.982mm^2/s for Jatropha, 4.706mm^2/s for WVO and 3.867mm^2/s for castor oil which was the lowest for B100. For B80 animal fat has the highest value of 4.679mm^2/s, while castor oil has the lowest value of 3.446mm^2/s. But for B50 and B20 WVO has the highest viscosity value 4.411mm^2/s and 4.118mm^2/s respectively, while castor oil has the lowest value of 3.082mm^2/s and 2.891mm^2/s respectively. The viscosities range from 2.892mm^2/s to 5.254mm^2/s for both the blends and the pure biodiesel. These values obtained were within the recommended ASTM range (1.9mm^2/s - 6.0mm^2/s at 40°C). According to Demirbas [25], viscosity refers to the thickness of oil which was determined by evaluating the amount of time taken for a given measure of oil to pass through an orifice of a specified size. Thus, both the pure and blended biodiesel will provide adequate lubrication for the precision fit of fuel injection pumps, guiding against leakages or increased engine wear.

The values of densities obtained for the various blends of biodiesel are shown in Fig.4 0.8870 g/cm^3 was observed to be the highest density value recorded for Jatropha oil and 0.8678 g/cm^3 was obtained for animal fat which is the lowest density value for B100. In other blends B80, B50 and B20 Jatropha oil still maintain the highest density values while animal fat has the lowest density values, with the lowest of all 0.8502 g/cm^3 for B20. The standard density range for biodiesel is 0.86 – 0.90 g/m^3. B100 and B80 have densities within the standard range, while B50 and B20 all except animal fats was within the biodiesel standard range. Density is mass per unit volume. The denser the oil the more energy it supplies to the engine [3]. Since density is an important parameter for diesel engine, the value should be maintained within the acceptable limits to allow optimal air to fuel ratio for complete combustion. To this end, blends from Jatropha, WVO and castor oil are preferable than blends from animal fat. However, the values obtained for B50 and B20 for animal fat fall within petro-diesel standard range 0.81 – 0.86 g/m^3 as reported by Van Gerpan [3], which is acceptable since it is a blend of petrol-diesel and biodiesel.

The cold weather properties which are the cloud point and pour point of biodiesel vary significantly with feedstock as seen in Figures 5 and 6. For B100, animal fats biodiesel has the highest cloud point of 17ºC and pour point 15 ºC, Jatropha oil has cloud point of 10 ºC and pour point of 8 ºC, WVO has a cloud point of 5 ºC and pour point of 4 ºC and castor oil has cloud point of -1ºC and pour point -2 ºC which is the lowest. For other blends B80, B50 and B20 the lowest value for both cloud point and pour point was recorded for castor oil while animal fat recorded the highest value of cloud and pour points. However, these values are within the ASTM standard range for biodiesel (-3ºC to 17ºC). Cloud point is the temperature at which oil starts to solidify. Operating an engine at temperatures below oil's cloud point is very problematic **[7]**.

The ASTM standard range for biodiesel pour point is -15°C to 12°C. Shown in Fig.6 above are values obtained for the B100 and all the blends. Pour point which is another cold weather property of biodiesel is the lowest temperature at which frozen oil can flow and is often used to specify the cold temperature usability of fuel oil [7]. The pour point obtained for all the blends and the pure biodiesel were within the recommended range. Therefore, it can be considered as an alternative fuel to petroleum diesel. Mushtaq *et al*., [26], reported that, biodiesel from castor oil has cloud point -6 ºC and pour point -9 ºC for B100. For other blends such as B50 and B20 the flash points are 86 ºC and 83 ºC respectively, the densities are 0.8872 and 0.8870 respectively, and the viscosities were found to be 4.43mm^2/sec and 3.98mm^2/sec respectively. The values obtained for the densities, viscosities and the cold weather properties are in agreement with this study as far as the ASTM standard is concerned, but the flash point is far below the ASTM range. Adepoju and Olawale, [21] reported the cloud point, flash point and pour point of biodiesel (B100) from waste cooking oil to be 9ºC, 114ºC and -13ºC respectively. Another work by Abdulkareem *et al*., [8], on Jatropha oil showed the density to be 0.88, viscosity to be 4.39mm2/sec at 40ºC, and flash point to be 142ºC for B100 which is in agreement with this work as well.

5. Conclusion

Despite the numerous advantages of biodiesel over diesel, the high cost of biodiesel production continues to be the bottleneck in commercial application. This is because of converting edible oil for biodiesel production. On like non-edible oil; it has no direct impact on food supply and cheap to purchase. This study has shown that biodiesel from non-edible oil possesses the quality to be accepted as an alternative fuel. Therefore, attention should be given to biodiesel production from non-edible oil for the purpose of commercial scale production. The biodiesel yield gave an encouraging amount compared with yield from a previous study on some edible oils such as palm oil, ground nut oil and corn oil with 95%, 93% and 75% respectively. The properties examined for the B100 and the blends were within the ASTM standard range.

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