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Production and Analysis of Biodiesel from Waste Vegetable Oil Feedstock

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***Abstract*—*The production of biodiesel from waste vegetable oil feedstock and ethanol was carried out in this work with the aim of investigating the effect of base catalysts (sodium hydroxide and potassium hydroxide) on the chemical and physical properties of the biodiesel produced. The biodiesel was produced using batch transesterification method. Some the parameters investigated included flash point, Cetane number, diesel index, cloud point, kinematic viscosity at 40 ^oC, density and so on. From the experimental results, the flash point was 164 ^oC, Cetane number 49, kinematic viscosity 5.87, cloud point 11 ^oC, and so on, when compared to the ASTM D6751 requirements were within the range specified for the various properties of biodiesel. It also shows that the values for the various chemical and physical properties are same or vary slightly for the base catalysts. Therefore the catalyst used does not affect the chemical and physical properties of the biodiesel produced from waste vegetable oil and ethanol. This further explores the principle of turning waste to wealth while contributing to a safer environment.*

***Keywords*—** *Base catalyst; biodiesel; chemical and physical properties; transesterification; waste to wealth; waste vegetable oil, safe environment*.

I. Introduction

The depleting reserves of fossil fuels, their adverse effects on the environment, cost, ever increasing energy demand to meet industrial and domestic needs, has increased and sustained the demand for alternative renewable energy sources that are cheaper, cleaner, biodegradable, less hazardous to the environment and easier to manufacture. Furthermore, the increased desire to reduce global warming and its negative effects, fuels that need to create an alternative energy scenario which is eco-friendly (Nair et al., 2017; Manzanera et al, 2008; Balusamy and Marrapan, 2007Mendez, 2006; Oluwaniyi and Ibiyemi, 2003).

Biofuels are of great value because of their eco-friendly nature since they are biodegradable and have significantly fewer noxious emissions than petroleum fuels when burned. A side effect of utilizing petroleum-based fuels is that over the years there has been a steady increase in the amount of pollution they produced. Their methods of extraction have also led to serious cases of oil spillage which tends to destroy the immediate or remote environment where such resources are found. This also has led to many political and socio-economic problems the world over. In view of these problems, it has become necessary to find other sources of fuels, as the fight against global warming cannot be won without a major deviation from the use of fossil fuels to the use of renewable energy. More so, the issue of deforestation can be corrected by use of bioethanol instead of wood alcohol (methanol). Bioethanol can be produced from any kind of starch/sugar containing bio matter. Biodiesel products from completely renewable sources cannot be overlooked (Khan and el Dessouky, 2009; Sharma and Singh, 2009; Hill et al., 2006; Pinto et al., 2005).

Biodiesel is a liquid fuel consisting of mono-alkyl esters of long chain fatty acids derived from vegetable oil or animal fats which can be used as a substitute for diesel fuel (Abdullah et al., 2017; Boz et al. 2009). It is designated as B100 and meets the requirements of ASTM D 6751. It is synthesized by the transesterification of triglycerides, the main component of vegetable oil and animal fats with mono-alcohol in the presence of a catalyst into fatty acid alkyl esters. The triglycerides are converted stepwise to di-glycerides, mono-glyceride, intermediates and finally to glycerin (Sukasem and Manaphan, 2017; Reefat, 2010; Alamu et al., 2007). Various types of engines today are made to run on a wide variety of fuels, such as premium motor spirit (petrol), diesel and gas as their primary fuel. With all these types of engines the compression ignition (diesel) engine is the most suited to run on biofuel. Its popularity could be attributed to its ability to use the portion of the petroleum crude oil that had previously been considered a waste product from the refining of crude oil (Liu et al, 2011; Singh and Singh, 2010; Frondal and Peters, 2007; Marchetti et al., 2007; Van Gerpen et al., 2004).

Most of the characteristics of biodiesel are similar to conventional diesel which allows the potential for competition and replacement. Biodiesel possesses a viscosity similar to fossil diesel, a relatively lower calorific value, higher octane number and flash point. Another advantage is that biodiesel are very similar to diesel fuel in composition therefore there is little or no need for engine modification to run on biodiesel (Romano and Sorichetti, 2011; Hameed et al., 2009; Sharma et al, 2008). The major difference between biodiesel and fossil diesel is their carbon content and the amount of carbon waste they expel into the atmosphere after they are used. Also biodiesel are produced from recently living things and fossil fuels are produced from long dead living things (Pinzi et al., 2009; Liang et al., 2009; Leung and Guo, 2006).

In Nigeria there is a huge potential for the development of biofuels as an alternative energy source. This is due to the fact that there are a wide variety of plants produced in the country that could be used as biofuel sources. Plants such as oil palm, jatropha, melon, soya bean, corn and sugar cane as well as waste vegetable oil can be produced and collected in large quantities for use as biomass or feedstock for use in fuel production. Among these, waste vegetable oil is of particular importance since it is a waste product and its use would mean

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recycling it and hence reduce environmental pollution (Bhuiya et al, 2017; Kareem et al., 2017; Maulidiyah et al., 2017; Elsoth, 2011; Meng et al., 2008; Zhang et al., 2008; Wang et al, 2007; Ecinar, 2005; Zhang et al., 2003). Nigeria is a major producer and exporter of fossil-based fuel that is crude oil and natural gas, yet it is unable to provide for the energy demands of its large population. Advances in the use of biodiesel as an alternative fuel source is aimed at providing cheap renewable energy, which is easy to manufacture and more importantly clean and more environmentally friendly energy. The production of this fuel can be encouraged at grass root level to aid ordinary Nigerians to manufacture and use biomass based oils as an alternative. This will fill the gap and more importantly relieve pressure on crude oil as the dominant fuel in the running of our everyday lives (Amigun et al., 2008; Oluwaniyi and Ibiyemi, 2003).

This study seeks to add to the continuous exploration of the potentials of biodiesel as an alternative fuel source. The main objective of this work is producing a fuel that is renewable and environmentally friendly and determination of the chemo-physical properties of biodiesel. The principle of waste to wealth (Lacy and Rutqvist, 2015; Sridhar and Hammed, 2014; Pappu et al., 2011; Olanrewaju and Ilemobade, 2009) is explored in producing biodiesel from a readily available biomass (waste vegetable oil) and the properties of the produced biodiesel compared with the standard ASTM D6751 specifications for biodiesel.

II. Materials and Methods

The waste vegetable oil (WVO) was collected from the neighborhood homes and eateries. The ethanol purchased from a chemical shop in Makurdi town was of 95% purity. It was then further dehydrated using a column evaporator to reach a purity of about 98%.

The free fatty acid (FFA) in the oil was estimated by titrating it against sodium hydroxide (NaOH) using phenolphthalein as indicator. 1 g of oil was weighted out into a 250 ml conical flask and 25 ml of diethyl ether was added to it, followed by 25 ml of ethanol. Two to three drops of phenolphthalein indicator was then added and titrated against 0.1 M NaOH. The content was constantly swirled till a pink colour which persisted for fifteen seconds was obtained. The FFA was calculated using (1).

$$FFA = \frac{Titre\ value \times Normality\ of\ NaOH \times 28.2}{Weight\ of\ Sample} \quad (1)$$

A density bottle was used to determine the density of the oil. A clean dry bottle of 25 ml was weighed and recorded as W_0. It was then filled with oil, a stopper was inserted and then weighed again and recorded as W_1. The oil was substituted with water after washing and drying, and then weighed to obtain W_2. The specific gravity was calculated using (2).

$$Specific\ Gravity = \frac{Weight\ of\ Sample\left(W_2 - W_1\right)}{Weight\ of\ water\left(W_2 - W_0\right)} \quad (2)$$

A sachet of a buffer powder with a pH of 7.0 was dissolved in 100 ml of distilled water, and then used to calibrate the pH meter. The pH meter was then used to determine the pH of the oil sample.

Due to the low free fatty acid (FFA) content of the waste vegetable oil (< 1%), there was no need for acid-catalyzed esterification for reduction of the FFA in an oil sample. Base-catalyzed esterification was used (Kara et al, 2017; Xiang et al, 2017; Reefat, 2010). The procedure for this using KOH is hereby presented. 300 ml of waste vegetable oil was measured and poured into a 500 ml conical flask. A solution of potassium ethanoxide was prepared in a 250 ml flask using 3.5 g of KOH pellets and 75 ml of ethanol. The solution was properly stirred till the KOH pellets were completely dissolved. The solution of potassium ethanoxide was then poured into the oil and the mixture placed in a water bath on a magnetic stirrer. The solution was heated to a temperature of 60-65 ^{o}C for 6 hours while being stirred. The mixture was allowed to settle for 24 hours, after settling the lower level which comprises of glycerol and soap was collected from the bottom of the separating funnel and the biodiesel collected. The biodiesel was filtered using filter paper to remove the excess glycerol and soap. The above procedure was repeated using a Sonex blender for 20 minutes instead of a magnetic stirrer for 6 hours.

The procedure for base-catalyzed esterification using NaOH is hereby presented. Also, 300 ml of waste vegetable oil was measured and poured into a 500 ml conical flask. A solution of sodium ethanoxide was prepared in a 250 ml flask using 3.5 g of sodium hydroxide pellets and 75 ml of ethanol, the solution was stirred till the NaOH pellets were completely dissolved. The solution of sodium ethanoxide was poured into the oil and the mixture poured into a blender and stirred for 20 minutes. The mixture was allowed to settle for 24 hours. After settling, the upper layer (biodiesel) was decanted into a separate beaker while the lower level which comprises glycerol and soap was collected from the bottom of the separating funnel. The biodiesel was filtered using filter paper to remove the excess glycerol and soap. Figure 1 shows some samples of the solutions during the filtration processes. The analysis of the properties of the final biodiesel was carried out at National Research Institute for Chemical Technology, Zaria.

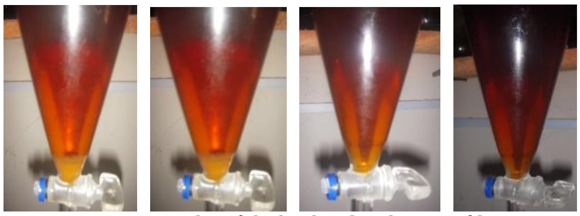

Fig. 1. Some samples of the biodiesel undergoing filtration.

III. Results and Discussion

The chemical and physical properties of waste vegetable oil investigated are given in Table I. When compared to standard specifications, it was observed that the specific gravity of the sample of 0.894 is within range of the standard. The FFA of the sample was also given at 0.564% which is less than 1% which indicates that it has low free fat content; hence it is suitable for biodiesel production. Another important property is the saponification value which for the sample was

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obtained as 207. This is within the standard range of 190-209. This indicates that the sample has high soap content.

TABLE I. Chemical and physical properties of waste vegetable oil.

Properties	Limits	Values
Refractive Index	1.454-1.456	1.455
pH		6.6
Free Fatty Acid	< 1%	0.564
Specific Gravity	0.889-0.895	0.894
Saponification Value	190-209	207
Acid Value	1.0-38.2	4.8

Results of test performed to compare the biodiesel produced using NaOH and KOH respectively against set standards are shown in Tables II and III. One of the more important characteristics of any fuel is its flash point; this is defined as the lowest temperature at which it can vaporize to form an ignitable mixture in air. The biodiesel samples have a higher flash point of 164 ^oC which as compared to the standard diesel flash point of 50 ^oC. This makes the biodiesel sample safe for use and storage. Fuels with lower flash point tend to ignite at lower temperatures making them highly dangerous if not stored and used properly. The Cetane number is another important property of fuels; this is a measurement of the combustion quality of diesel fuel during compression ignition. Generally diesel engines will run with values of between 40 and 55. The biodiesel produced had a value of 49 which is well within range and indicates that it is suitable to run in diesel engines. Viscosity of the fuel is also another important value; it is the measure of resistance to flow of liquid due to internal friction of one part of a fluid moving over another is of utmost importance in the use of fuels, the higher the viscosity, the greater the tendency of the fuel to cause problems such as clogging the engine components. The esterification process reduces the viscosity to that closer to fuels required by a vast majority of engines. With a viscosity value of 5.87 mm^2/s against the maximum 6.0 mm^2/s this particular sample of biodiesel is within range to be used as pure biodiesel or blended with regular diesel for engine use.

TABLE II. Properties of biodiesel produced from waste vegetable oil using NaOH.

Property	Method	Limits	Results	Units
Flash point (pensky-martens closed cup)	D93	130 min	164	^oC
Diesel index	D975		5	^oC
Kinematic viscosity at 40^oC	D445	1.9-6.0	5.87	mm^2/s
Pour point			7	^oC
pH			7.6	
Copper strip corrosion	D130	No. 3 max	ND	
Cetane number	D613	47 min	49	
Cloud point	D2500	Report to customer	11	^oC
Heat of combustion	D240		40849.09	kJ/g
Peroxide value	D2274		8.4	
Moisture content			0.12	%
Density	D4052-91		890	kg/m^3
Vacuum distillation end point	D6751	360^oC max T-90	332	^oC
Refractive index			1.263	

A close inspection of the experimental results in Tables II and III shows very close similarity between the properties of the products when NaOH and KOH were used. This shows that the base catalyst used does not affect the chemo-physical properties of biodiesel produced from waste vegetable oil.

Furthermore, this is a good avenue to transform the domestic and industrial waste vegetable oils into wealth by producing biodiesel which can be used to produce clean energy. It will promote better waste management thereby improving the environmental quality while reducing the negative influence of combusting fossil fuels for transport and industrial applications. The production and use of biodiesel using the locally available waste vegetable oil is hence viable for use either as 100% biodiesel (B100) or in combination with regular diesel in proportions up to 20% biodiesel.

TABLE III. Properties of biodiesel produced from waste vegetable oil using KOH.

Property	Method	Limits	Results	Units
Flash point (pensky-martens closed cup)	D93	130 min	163.9	^oC
Diesel index	D975		5	^oC
Kinematic viscosity at 40^oC	D445	1.9-6.0	5.86	mm^2/s
Pour point			7	^oC
pH			7.5	
Copper strip corrosion	D130	No. 3 max	ND	
Cetane number	D613	47 min	49	
Cloud point	D2500	Report to customer	11	^oC
Heat of combustion	D240		40840.1	kJ/g
Peroxide value	D2274		8.4	
Moisture content			0.12	%
Density	D4052-91		887	kg/m^3
Vacuum distillation end point	D6751	360^oC max T-90	331	^oC
Refractive index			1.263	

Materials used in the production of biodiesel are readily available without the need of highly specialized and technical equipment or scarce chemicals. As a result with specific encouragement in the spirit of economic diversification of the federal government of Nigeria, pilot plants can be set up for small localities for the production of this biodiesel from waste vegetable oil and ethanol without the use of very highly specialized and technical equipment. This can be in collaboration to the various Universities and Research Institutes.

IV. Conclusion

The simple transesterification process of waste vegetable oil sample yielded biodiesel with properties comparable standards. This process is simple, cheap and clean. The results obtained also confirmed that the use of base catalyst does not affect the chemo-physical properties of biodiesel produced. This has great potentials to add to the mix of the continuous search for renewable, clean and eco-friendly energy options while boosting the economic fortunes of local communities.

Government should encourage setting up of biodiesel production plants through policy and direct involvement with the private sector and academic and research institutions. These plants would produce biodiesel from various feedstock including waste vegetable oil that could be gotten from restaurants and food stalls as well as homes scattered across the country. Furthermore, University authorities should set up a biodiesel production and research facilities that will encourage students to carry out research and analysis on biodiesel within the campus as this will reduce cost of research for both staff and students.

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