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PRODUCTION OF BIODIESEL FROM USED VEGETABLE OIL

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Abstract

Investigation harnessing waste oil discarded into streams, water ways and farm lands by producing biodiesel which can curb the environmental menace caused by emission from petrol diesel. Used vegetable oil from an eatery was intercepted at the point of being discarded and used as the main material for this work. 2 litres of the oil was sieved, warmed up and made to react with 8grms of sodium hydroxide and 400 mls of methanol in a trans-esterification reaction leading to the production of biodiesel and glycerine. The density difference between the two made separations easy, leaving glycerine at the bottom of the container and biodiesel at the top which was collected, washed severally and dried by exposure to air. It was found the biodiesel produced from used vegetable oil gave a better engine performance and less emission than the petrol diesel.

Key words*: Biodiesel, used vegetable oil, transesterification, alcohol.*

1.Introduction

Biodiesel is a fuel for diesel engines made from plant or animal oils. There are several sources of getting oil which is the raw material needed for biodiesel production and these include non-edible oil, animal fat and vegetable oil. Jatropha plant/oil seed of specie Jatropha curcas which gives non edible oil was cited in 2007, by Goldman Sachs as one of the best candidates for future biodiesel production. Jatropha has a good resistance with pests and drought, and can produce seeds containing 27-40% oil while the residue (press cake) can also be processed and used as biomass feedstock to power electricity plants or used as fertilizer as it contains nitrogen, phosphorus and potassium[1,2]. Currently in Philippines and in Brazil the oil from *Jatropha curcas* seeds are used for making biodiesel fuel. Jatropha oil is being promoted as an easily grown bio fuel crop in hundreds of projects throughout the world. The railway line between Mumbai and Delhi is planted with *jatropha* and the train itself is being run on 15-20% biodiesel[3]. The oil used in biodiesel fuel production can be fresh clean oil or used waste oil that has been earlier used for frying as in this study. The fact is lots of energy is stored in oil(liquid) and fat(solid) and biodiesel is all about getting that energy back to power engines/ vehicles down the highway. Lately, the emphasis on the production of liquid fuels from renewable sources have been on the increase and biodiesel has been proposed as one of those fuels because its production can be carbon-neutral. Vegetable oil was first transesterified in 1853 by E Duffy and J Patrick. In 1893, Rudolph biodiesel's first engine was demonstrated. The biodiesel engine went on to win the Grand Prix at the World Fair of 1900 which took place in Paris[4].

The engine demonstrated in Paris ran oil made from peanut. Biodiesel plants have opened in many European countries since the 1980s and some cities have run buses on biodiesel, or blends of petro and bio diesels. It is on record that Peugeot and Renault have approved the use of biodiesel in some of their truck engines[4]. Biodiesel derived from vegetable oil or animal fat by transesterification with alcohol like methanol or ethanol, is recommended for use as a substitute for petroleum based diesel because biodiesel is oxygenated, (the gasses released during combustion are essentially the gasses absorbed from the atmosphere whilst the plant was growing.) It is renewable, biodegradable and environmental friendly[5]. Global warming gas emissions such as carbon dioxide, carbon monoxide, hydrocarbon and particulate matter in the exhaust gas is minimised compared with petroleum based diesel fuels. Biodiesel is a better lubricant than petro diesel as it helps to extend the working life of engines [6].

Biodiesel reduces risks from respiratory problems as it gives fewer particulates[6] when burnt making it easier to ignite than petrol diesel, thereby leading to a complete, efficient combustion[6]. However biodiesel is more expensive to produce than petro diesel and if grown on a wider scale, more plants for oil would be grown as cash crop. This may reduce the amount of food grown to feed the population in less economically developed countries. Biodiesel gels at lower temperatures than petro diesel, so tanks require heating in cooler climates and degrades rubber hoses if used on older engines[7]

1.1 Source of material:

Several sources such as non-edible oil, animal fat and vegetable oil can be used as raw material for biodiesel production as earlier mentioned. However, the vegetable oil extracted from plant that are composed of triglycerides was used because it contains similar fuel properties to diesel fuel except the higher viscosity and low oxidative stability that must be encountered before being converted into biodiesel. So, the vegetable oil mostly used in transesterification reaction include straight vegetable oil and waste vegetable oil as in this case study.

1.2 Straight Vegetable oil

Pure plant oil or commonly known as straight vegetable oil is not a by-product of other industries either coming from domestic usage. The straight vegetable oil is a highly grade oil extracted primarily from plant, usually, seeds of oilseed plants [6]. In addition, this oil is the best starting material compared to waste cooking oil because of the conversion of the triglyceride to the fatty acid component and availability of methyl ester is high making the reaction time relatively short.

1.3 Waste Cooking Oil:

Waste cooking oil is one of the alternative sources among other higher grade or refined oil[7] Waste cooking oil is easy to collect from other industries such as domestic usage and restaurant[7] and also cheaper to produce in small quantities than the refined oil. Hence by using this oil as the raw material, the cost of biodiesel production is drastically reduced, thus, the low cost advantage and prevention of environmental pollution. Many individuals dispose waste cooking oil directly to the environment especially in rural area but this same oil could be used in biodiesel production and generate energy.

1.4 Solvent:

In transesterification process the main solvent used is alcohol. The examples of alcohols that could be used in the transesterification of triglycerides are methanol, ethanol, propernol, butanol and amyl alcohol[8]. Methanol is the most widely used because of its low price and its physical and chemical advantages (polar and shortest chain alcohol) it can quickly react with triglycerides and sodium hydroxide and easily dissolve in it.

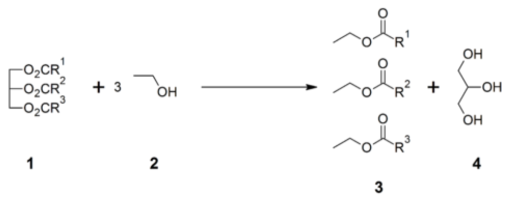
1.5 Catalyst:

A catalyst is used to hasten up the process and Sodium hydroxide (NaOH) and potassium hydroxide (KOH) are the common catalyst used[9,10,11,12,13] in the reaction process.

2.0 Methodology

2.1 collections of sample and preservation

Used vegetable oils were collected from eateries and restaurants in wuse 2; Abuja-Nigeria. The used vegetable oil was sieved and collected in a glass ware/container, placed on a hot plate to warm up to about 60^{o}c to remove any trace of water. 16g of NaOH (caustic soda) was added into 800mls of methanol in (sodium) another glass container and continuous stirring was applied until all the caustic soda was dissolved, resulting in a compound known as sodium methoxide which was then added into the beaker containing the vegetable oil. The transesterification led to our biodiesel and a by product known as glycerine. Due to the sharp density contrast between the biodiesel and glycerine, the glycerine settles at the bottom of the beaker/container and could be separated easily .After which the biodiesel was repeatedly washed with warm water to remove the remaining methoxide from it. Washing with warm water was done 5 times and the introduction of warm water was done gently. Stirring was completely avoided to prevent soap formation. The water got clearer as washing continued. After each introduction of warm water, the cloudy solution is sieved out and warm water added again repeatedly. Drying was done by exposing the biodiesel to air in an open container. Thus 4 litres of biodiesel was produced from 4 litres of used vegetable oil and 800mls of sodium methoxide.
Biodiesel is made by transesterification of vegetable oil. Fat and oil share a basic structure, with a glycerine backbone supporting fatty acid chains.



The carbon atoms on the left-hand side form the backbone of the glycerine, and the bits hanging on are the fatty acids, where the R represents a long hydrocarbon chain.

The glycerine left behind settles out and can be used for consumer products like moisturizers or made into soap. If you start with used vegetable oil as in this case study, a lot of free fatty acids will be floating around. These fatty acids can undergo a reversible acid-base reaction with the methoxide to produce methanol and a fatty acid salt which is the soap.

2.2 Analytical Determination

2.2.1 Specific Gravity

A 10 ml specific gravity bottle was used to carry out the specific gravity. The pre-weighted bottle was filled with the fuel sample to its brim and the final weight of the bottle was taken to give the weight of the sample which when divided by 10 gave the specific gravity and the density of the sample.

2.2.2 Pour Point

For the pour point, the sample and kept in an Ultra Low Temperature Refrigerator of -80^{0}C with a test tube. The fluidity was checked after every 5°C drop in temperature by bringing out the sample and checking. At the particular temperature the liquid ceases to flow, is known as the pour point and this was recorded.

2.2.3 Flash Point

Pensky Martin Apparatus was used to determine the flash point. 30 ml of the sample was collected in the apparatus cup and cooled using a water bath. Stirring was done continuously during the process. After every 1°C fall in temperature, the vapour of the sample was exposed to a flame. Flash point is the point at which fire starts with a flash.

2.2.4 Moisture content

With the aid of a moisture analyser, (Sartorius MA35) the moisture contents were determined at a programmed temperature of 105 ⁰C and total moisture content, determined gravimetrically by measuring the weight loss of solid sample with increasing temperature until there was no further weight loss at the programmed temperature.

2.2.5 Copper strip corrosion Tarnish test ASTM-D130-Test Method

D 130 can be used to detect the presence of free sulphur or reactive sulphur compounds. In this test method, a polished copper strip is immersed in 30 ml of sample and heated to 50 ^{o} C for 3 hours. The test strip is compared to standard strips and reported on a scale of 1 to 4 (1 is the best).

2.2.6 Kinematic viscosity: ASTM-D445-Kinematic viscosity of transparent

The sample is placed in a calibrated capillary glass viscometer tube, and held at a closely controlled temperature. The time required for the specific volume of the sample to flow through the capillary under gravity is measured; this time is proportional to the kinematic viscosity of the sample.

2.2.7 Carbon residue ASTM D 524- Rams bottom carbon residue products or Conradson apparatus

The sample is first distilled (ASTM D86) until 90 % of the sample has been recovered. The residue is weighed into a special glass bulb and heated in a furnace to 550 ^{o} C (1,022 ^{o} F). Most of the samples evaporates or decomposes under this condition. The bulb is cooled and the residue weighed

3.0 Results and Discussion

3.1.1 The results for the properties of the biodiesel produced are presented in Table 1. The used vegetable oils had a density of 0.865 at 15°C, kgm-^{3}, and a Kinematic viscosity of 4.0 (mm^{2}s^{-1}) @ 40 ^{o} C, a heating value of 40073 KJ/Kg, a copper corrosion strip of 1a, a moisture content of < 0.01. The used vegetable oils gave a flash and Pour points (^{o} C) of 145 and -16respectively, and the ash contents and carbon residue (%mass) of the vegetable oil was 0.018 and 0.18 respectively.

Table I .Properties of used cooking oils

Properties of used cooking oils	**value**
Heating Value (KJ/Kg)	40073
Flash point (^{0}C)	145
Kinetic viscosity (mm^{2}s^{-1}) @ 40^{0}C	4.0
Copper strip corrosion	1a
Density (specific gravity) (15^{0}C, kgm^{-3})	0.865
Sulphated Ash content (% mass)	0.018
Carbon residue (% mass)	0.18
Pour point (^{0}C)	-16
Moisture content (% vol)	< 0.01

3.1.2 Used vegetable oils from my study had a Density (15°C, kgm-^{3}) of 0.865, which was higher than those of *Jatropha Curcasa* Biodiesel from a different study, and cottonseed biodiesel which both had values of 0.850, but was lower than those of castor biodiesel which had a value of 0.957. The kinematic viscosity was 4.0, lower than the values, *Jatropha Curcasa* Biodiesel (4.8), castor biodiesel (24), and cotton seed oil (7.2). The copper strip corrosion of the used vegetable oil was 1a, while that of castor biodiesel was 1b. The Flash point of the bio diesel was 145, and that of *Jatropha Curcasa* Biodiesel (135), lower than that of castor biodiesel. The Pour point of the used vegetable oil was -16, and lowers than that of *Jatropha Curcasa* Biodiesel which is 2. The moisture content of the used vegetable oil was less than 0.01, and was lower than that of *Jatropha Curcasa* Biodiesel 0.025. The ash content of the used vegetable oil in our study was 0.018 (% mass) higher than that of *Jatropha Curcasa* Biodiesel 0.012 (% mass) from a different study. The carbon residue of the used vegetable oil was 0.18, and was found to be higher than that of castor biodiesel (0.037 % mass), but lower than that of *Jatropha Curcasa* Biodiesel (0.20 % mass). The heating value of the used vegetable oil was 40073 (KJ/Kg), and was higher than those of castor biodiesel (38905.8) from a different study.

Table 2: Comparison of the properties of the biodiesel produced from used vegetable oils with biodiesel from other sources.

Properties	**Our study**	**Waste cooking oil**	***Jatropha*. biodiesel**	**Castor bio diesel**	**Cotton seed biodiesel**
Density (Specific gravity) (15°C, kgm-^{3})	0.865	-	0.850	0.957	0.845
Kinematic viscosity (mm^{2}s^{-1}) @ 40 ^{o} C	4.0	1.9-6.0	4.8	24	7.2
Copper strip corrosion	1a	-	-	1b	-
Flash point (°C)	145	130	135	200	-
Pour point (°C)	-16	-	2	-	-
Moisture content (% vol)	< 0.01	0.05	0.025	-	-
Sulphated Ash content (% mass)	0.018	-	0.012	-	-
Carbon residue (% mass)	0.18	-	0.20	0.037	-
Heating value (KJ/Kg)	40073	-	-	37900.8	-

3.1.3 The results for the comparison of the properties of the biodiesel produced from used vegetable oils and those from fossil diesel are presented in Table 3.4. The used vegetable cooking oil from our study gave a density value of 0.865 (15°C, kgm-^{3}), which was higher density than those from different , Petroleum diesel, Diesel fuel, and fossil diesel, which had values of , 0.8610, 0.850, and 0.880 (15°C, kgm-^{3}) respectively. The used vegetable oil had a kinematic viscosity of 4.0 (mm^{2}s^{-1}) @ 40 ^{o} C, which was higher than those of, Petroleum diesel, Diesel fuel, and fossil diesel, which had values of , 3.81, 2.6, and 2.27 mm^{2}s^{-1} @ 40 ^{o} C respectively. The used vegetable oil was observed to have copper strip corrosion of 1a, and had a similar value to that of Petroleum diesel also 1a. The used vegetable oil had a flash point (^{o} C) of 145, and was higher than that, Petroleum diesel, Diesel fuel, and fossil diesel, which had values of, 68.3, 68, and 47 ^{o}C respectively. The used vegetable oil was observed to have a value of -16, which was lower than that of Petroleum diesel -6, but higher than that of diesel fuel -20. The moisture content (% vol) of the used vegetable oil from our study was < 0.01, and was found to be lower than Diesel fuel 0.02 (% vol) respectively. The ash content of the used vegetable oil biodiesel was 0.018 (% mass), and was found to be higher than those of Diesel fuel, which had values of 0.010 (% mass). The carbon residue of the used vegetable oil biodiesel was 0.18 (%mass), and was found to be higher, which had a value of 10 (%mass), and Petroleum diesel which had a value of 0 (% mass). The heating value of the used vegetable oil biodiesel was 40073 (KJ/Kg), and was found to lower than the value for Petroleum diesel, which had a value of 47216.5 KJ/Kg.

Table 3: Comparison of properties of biodiesel from used vegetable oil with those of fossil diesel

Properties	My study	Petrol diesel	Diesel fuel	Fossil diesel
Density (Specific gravity) (15°C, kgm-^{3})	0.865	0.8610	0.850	0.880
Kinematic viscosity (mm^{2}s^{-1}) @ 40 ^{o} C	4.0	3.81	2.6	2.27
Copper strip corrosion	1a	1a	-	-
Flash point (°C)	145	68.3	68	47
Pour point (°C)	-16	-6	-20	-
Moisture content (% vol)	<0.01	-	0.02	-
Sulphated Ash content (% mass)	0.018	-	0.01	-
Carbon residue (% mass)	0.18	0	-	-
Heating value (KJ/Kg)	40073	47216.5	-	-

3.2 Discussion

Biodiesel derived from vegetable oil or animal fats by trans esterification with alcohol like methanol or ethanol, is recommended for use as a substitute for petroleum based diesel mainly because biodiesel is oxygenated, (since the gasses released during combustion are essentially the gasses absorbed from the atmosphere whilst the plant growing).It is renewable, biodegradable and environmental friendly with similar flow and combustion properties of the petrol. Biodiesel helps to reduce global warming gas emissions such as carbon dioxide, carbon monoxide, hydrocarbon and particulate matter in the exhaust gas compared to petroleum based diesel fuels, and the lubricating power of biodiesel is stronger than petrol diesel, so it helps to extend the working life of engines. the particulates biodiesel gives out while burning is very few, thereby reducing risks from respiratory problems. Biodiesel is easier to ignite than petro diesel, meaning more complete, efficient combustion. *However*; Biodiesel is more expensive to produce than the conventional petro diesel in a wider scale as more plants for oil would be grown as a cash crop, reducing the amount of food grown to feed the population in less economically developed countries. Biodiesel forms a gel at lower temperatures unlike petro diesel, so tanks require heating in cooler climates and rubber hoses of older engines tend to degrade so would need frequent replacement.

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