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PROSPECTS OF BIODIESEL PRODUCTION FROM FOOD CROPS IN LAGOS

[1]HUMPHREY, Ibifubara, [1]OBOT, I. Nsikan, [1]OLUGBON, Busola, [1]OYEBOLA, O. Olusola.

[1]Department of Physics, University of Lagos, Akoka, Lagos, Nigeria

🖂: ihumphrey@unilag.edu.ng; +(234) 08034430069

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Abstract:
The energy crisis in Nigeria is still severe and persistent due to the country's expanding population and the resulting rise in energy consumption, as well as its underdeveloped electrical energy infrastructure and the massive issues with conventional energy sources such as continual gas flaring. This research compares the quality of various biodiesel blends made from various vegetable oils. Through a transesterification reaction, biodiesel was made from animal fat oil and bleached palm, corn, cottonseed, peanut, and soya oils. Four blends' (B20, B50, B80 and B100) physiochemical characteristics were measured to check for compliance in accordance with the ASTM standard for biodiesel. The results show that the bulk of the feedstock has a high percentage yield, with bleached palm oil having the highest yield (95%), and animal fat having the lowest yield (61.5%). Viscosity was measured at temperatures ranging from 10°C to 60°C, with animal fat B100 having the highest value (7.717 mm2/sec) at 10°C and corn oil B20 having the lowest value (1.840 mm2/sec) at 60°C. Furthermore, the sulfur content, flash point, density, and cold point readings were all within the ASTM standard range.

Keywords: **Biodiesel; Energy; Physiochemical; Food crops; Transesterification; Blend; Lagos.**

1. INTRODUCTION

Energy is essential for maintaining and improving the current phase of human life. Today's technology, which includes home appliances, automobiles and communication devices, as well as devices used in banking, healthcare, leisure and other fields, all require energy to function. Energy sources can be divided into two categories: renewable and non-renewable. Energy that is not renewable can be considered as conventional sources are the fossil fuels such as crude oil, nuclear power and gas. The non-renewable energy sources are exhaustible, although they are the most advanced energy sources used to power vehicles and generate electricity. Due to the tremendous development and investments that have been enjoyed, the efficiency level of non-renewable energy sources is much higher than that of their counterparts, apart from their enormous utilization possibilities (Dahlke *et al*., 2021).

Nonetheless, there are well-known energy-related problems such as epileptic power generation and supply, missing meters, huge estimated electricity bills that do not match consumption and supply, among others in some developing countries such as Nigeria. However, urbanization, population explosion and energy demand continue to increase in the face of these energy-related problems.

Additionally, those who can afford to generate electricity from generators exacerbate the problems by eventually contributing to noise and air pollution. Though, efforts are currently being made to solve the problems associated with power generation, transmission and supply (Ohunakin, 2010).

Lagos is one of the most densely populated regions in Nigeria, yet it is the smallest in landmass. The effects of overpopulation also pose health challenges. Aside from the unpredictable changes in international oil prices, the prices of local petroleum products continue to rise despite claims of government subsidies. The issues with non-renewable energy sources were noted, and alternative energy sources were proposed as a remedy. Despite the fact that using non-renewable energy sources causes air pollution, which subsequently contributes to climate change, unlike the underdeveloped alternative energy sources, the non-renewable energy sources are highly developed and immediately cheaper to install due to the high subsidy it enjoys (Ezema *et al*.,2016).

Besides, there are no enticing regulations for the use of renewable energy sources in developing countries. For example, excess electricity generated privately using alternative means such as photovoltaic (PV) systems can be sold to the public grid in developed countries. Therefore, as a renewable energy source, biodiesel can be produced from halophyte oil, virgin oils, algae, used vegetable oils, and animal fats. Compared to traditional fossil fuels, Some benefits of using biodiesel as an alternative fuel source is that it is renewable, has a low sulfur content, is biodegradable, emits few emissions, has a high combustion efficiency, and has a high aromatic calorific value (Bajpai and Tyagi, 2006). In addition, biodiesel has reduces engine wear over time, easy cold starts, extending fuel injection system life and low idle noise. Its higher lubricity than any other fuel has been demonstrated (Barnwal and Sharma, 2005). With less soot in the vehicle's exhaust and a pleasantly fruity aroma, it also enhances the environment (Bencheikh *et al*., 2019).

Long-chain fatty acids with an alcohol linked make up biodiesel, which is frequently made from vegetable oils. In the presence of a catalyst, it is produced by the reaction of a vegetable oil with ethyl alcohol or methyl alcohol. (Van Gerpen, 2005; Mofijur et al., 2013). Potassium hydroxide (KOH) and sodium hydroxide are both frequently used catalysts (NaOH). Transesterification is the name of the chemical reaction that yields glycerin and biodiesel (Knothe *et al*., 2000). If methanol is used as the alcohol, biodiesel is referred to chemically as a methyl ester. An ethyl ester is a compound that contains ethanol (Knothe, 2005). They are comparable, and at the moment, methyl ester is less expensive because methanol is less expensive. For usage in compression ignition engines, a certain amount of biodiesel can be used either alone or in combination with diesel fuel (Demirbas, 2008; Bashir *et al*., 2022).

First generation, second generation, and third generation biodiesel are the three classifications available. The term "first generation biodiesel" refers to biodiesel made from food crops like sugarcane, peanuts, soybeans, and starchy plants. The use of algae and other microbes in the synthesis of biodiesel represents the third generation, which is occasionally placed under the second generation when only two classifications are specified. This classification relates to the times of discovery. In the second generation, non-edible plants like jatropha and industrial, residential, and agricultural waste like sawdust, animal manure, and cassava piles are used. (Ashraful *et al*., 2014; Altaie *et al*., 2015).

Currently, 14% of the world's principal source of energy consumption comes from biomasses (Shah and Venkatramanan, 2019). Due to a regulation established in 2005, individuals are encouraged to produce and sell biodiesel in Brazil, all diesel sold by 2010 must contain a B5 biodiesel blend for use in vehicles (Ramos *et al*., 2019). Since soybeans are essentially available in Brazil, low taxes have been put in place to promote the production of biodiesel, especially for small-scale farmers who are primarily interested in palm and castor oil crops. These initiatives caused the output of biodiesel in Brazil to steadily increase, from zero million m3 in 2005 to over 1,500 million m^3 in 2009. The global biodiesel market was worth $23670 million in 2020 and is anticipated to be worth $26270 million by the end of 2027 (Datta *et al*., 2021).

The majority of the people in Nigeria lives in poverty despite the country's comparatively substantial economic incomes, which are mostly from crude oil. The main activity is farming, and the country has a high unemployment rate as a result of resource mismanagement, theft, embezzlement, and an uneven distribution of resources (Akpokighe and Ejovi, 2020). The manufacture of biodiesel from vegetable oil would create employment possibilities to help lower the high unemployment rate in the nation. The initial phase of this work, which demonstrated the potential of used vegetable oil to make biodiesel, was previously reported (Humphrey *et al*., 2017). The purpose of this study is to produce biodiesels from various vegetable oils and compare them in order to determine whether or not rural residents may use the creation of biodiesel to meet some of their energy demands, depending on accessibility and availability.

2. MATERIALS AND METHOD

2.1 Procedure

To produce biodiesel, a process called transesterification separates glycerin from vegetable oil or fat (feedstock). The theoretical alcohol to catalyst molar ratio in a transesterification reaction is 30 ml to 1.06 g while the theoretical alcohol to oil molar ratio is 1:3. More alcohol is recommended to shift the equilibrium position in favor of the product and speed up the conversion to biodiesel since transesterification is a reversible reaction. A butcher in Lagos provided the animal fat, while the other oils, soybeans, peanuts, cottonseed and bleached palm and corn were bought at the market 100% refined oils as feedstocks. In an airtight, flat-bottomed flask measuring 500 mL, the transesterification reaction was conducted. An empty flask was filled with 200 mL of each starting material, which was then heated to a temperature of 55°C. Potassium methoxide (KCH_3O) was added to the flask containing the oil after it was generated by dissolving 2.12 g of Merck grade potassium hydroxide pellets in 70 mL of 99.8% pure Analar grade methanol. To prevent alcohol from escaping, the reaction was carried out in a closed system. During the one-hour reaction time, the system temperature was maintained between 60 and 65 ^{o}C (Methanol escapes from the reaction mixture when it reaches its boiling point of 65 ^{o}C).

Following the procedure, the solution was placed into a 500 mL separating funnel and allowed to sit for 24 hours so gravity could separate the biodiesel from the glycerol. The remaining glycerol, catalyst, and other contaminants were then removed from the biodiesel by washing it five times in warm water until the pH was neutral. A heating element was used to dry the biodiesel for approximately 1 hour and 30 minutes (depending on the relative humidity of the country).

2.2 Determination Of Physico-Chemical Properties

The following physicochemical properties were observed: In accordance with ASTM D93-11 Standard Test Method for Flash Point, the flash point was estimated using an automated Pensky-Martens closed cup apparatus over a temperature range of 60 to 190°C. At various temperatures, the viscosity was evaluated using an Anton Paar SVM 3000 digital viscometer. The amount of sulfur was determined using ASTM D5453. Density was obtained using a density bottle. Cloud and pour points were also evaluated in accordance with ASTM D6371-05 Standard Test Procedure for Heat and Cold Filter Plugging Point of Diesel Fuels. The ASTM standards for biodiesel and petroleum diesel.

3. RESULTS

3.1 Percentage yield of biodiesel production

The results of studies on the basic physical and chemical properties of biodiesel in the three (3) blends B20, B50 and B80 include the purest form, B100. All measurements are in milliliters, including the amount of feedstocks used, the percentage of free fatty acids (FFA), the amount of biodiesel produced and the corresponding percentage yield. Bleached palm oil yield was highest (95%) followed by peanut oil (93%), although all feedstocks were transesterified under the same conditions. Cottonseed oil had the highest yield at 77.5%, followed by soybean and corn oil at 75% each, and animal fat at 61.5%. Because FFA combines with alkali catalysts to create soaps that hinder the process, the percentage yield is inversely proportional to the FFA, meaning that the lower the FFA, the higher the percentage yield. This is shown in Fig.1.

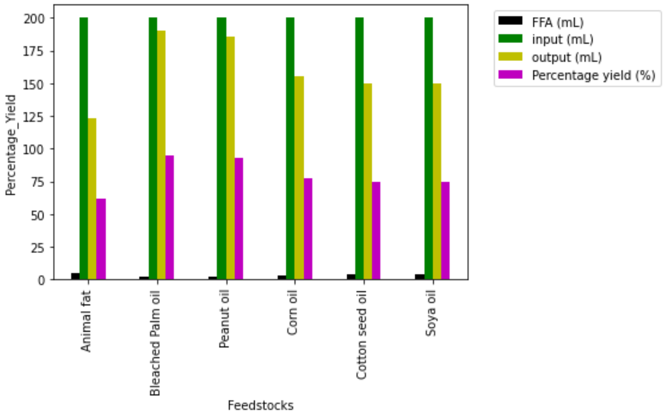

Fig.1: Percentage yield of biodiesel production

3.2 Densities of Biodiesel Blends

The density of a material is expressed in grams per cubic centimeter (g/cm^3). Oils with increased density contain more energy. For example, diesel fuel is thicker than gasoline and has the same energy content by weight, but more energy per liter. The values of the densities for the various biodiesel blends are shown in a bar chart in Fig. 2.

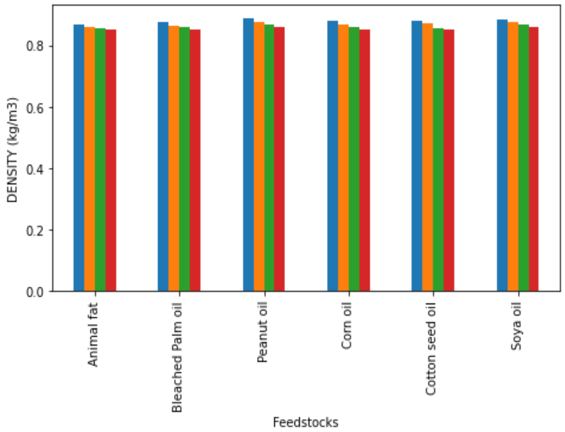

Fig. 2: Densities of Biodiesel Blend

Compared to the B20, B50 and B80 biodiesel blends, B100 from peanut oil had the highest density (0.8867 g/cm^3) and B100 from animal fat the lowest (0.8678 g/cm^3) of all biodiesel blends. For biodiesel the normal density range is between 0.86 and 0.90, but for petroleum diesel it is between 0.81 and 0.86. This proves that the B100s densities fall within the expected range. The B80 also meets the requirements of the biodiesel standard. Since B50 is a mixture of petroleum diesel and biodiesel, all but the animal fats are within the permissible range for biodiesel. However, the animal fat is still within the acceptable range for mineral oil diesel. Peanut and soybean oils fall within the normal biodiesel range for B20, but corn, animal fat, cottonseed and palm oils fall within the standard petroleum diesel range. The qualities of density and other gravities are essential to diesel fuel injection systems. The value must be kept within allowable limits to allow proper air-fuel ratios for complete combustion. According to Tat and van Gerpen (2000), high-density biodiesel or its blend can lead to incomplete combustion and particulate emissions.

3.3 **Determination of Biodiesel Sulfur Content**

According to the findings, animal fat has a higher sulfur content than the other raw materials. However, none of the biodiesel samples or blends examined in this study had a sulfur content greater than 15 ppm. The sulfur contents of the vegetable and animal fats examined are very different. The results demonstrate that all of the feedstocks evaluated in this study can be used to produce biodiesel with 15 ppm or less sulfur with proper oil extraction, biodiesel conversion and post-reaction treatment. Figure 3 shows a sulfur content plot for the different biodiesel blends examined in this study. The Environmental

Protection Agency requirements (15 ppm) for road diesel fuels effective June 1, 2006 are met by the sulfur levels achieved for B100 and blends.

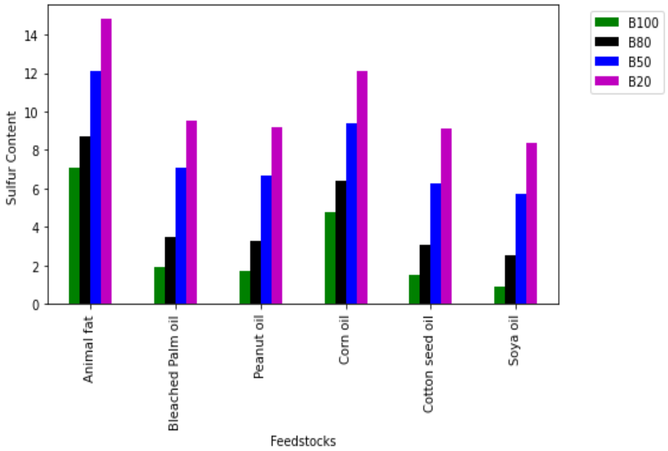

Fig. 3: Sulfur Content of Biodiesel

3.4 Determination of Biodiesel Viscosity

A liquid's viscosity is a measure of how difficult it is for it to flow. It explains how a flowing fluid experiences internal friction. Because of the significant internal friction created by its molecular structure, a high viscosity liquid resists movement, while a low viscosity liquid flows smoothly. The fluid moves more easily when it is viscous (fluidity). The length of time it takes for a given volume of liquid fuel to pass through an orifice of a given size is used to measure the viscosity of liquid fuels. According to Doan and Temur (2013), viscosity affects both fuel atomization and injector lubrication. High-viscosity fuels, on the other hand, often result in larger droplets when injected, which can result in inefficient combustion, more exhaust smoke, and more emissions. Low-viscosity fuels can cause leaks or increased wear because they don't provide enough lubrication for the fuel injection pumps to seat properly. Fig. 4, a plot of viscosity in mm versus temperature in °C, shows that viscosity increases as the proportion of biodiesel blend increases and decreases as the temperature increases.

The B100 animal fat at 10 ^{o}C yielded the maximum viscosity measurement of 7.717 mm^{2}/s, while the B20 maize oil at 60 ^{o}C yielded the lowest measurement of 1.940 mm^{2}/s. Viscosity measurements for each blend were found to be within the ASTM acceptable range of 1.9 to 6.0 mm^{2}/s for biodiesel at 40°C. Viscosity increases with decreasing temperature at low temperatures, that is, temperatures below the reference temperature of 40°C. All of the blends were found to be within the approved range at 20 ^{o}C, although for B100 peanut, bleached palm oil and animal fat showed results that were higher than the value that was advised.

Additionally, at 10 ^{o}C, Values for B100 for all biodiesels are over the advised range, but their blends are within the range. Biodiesel B100 without a blend is not suitable for use in a diesel engine at low temperatures due to its high viscosity value. High levels of viscosity affect fuel fluidity, resulting in poor fuel spray atomization and inaccurate fuel injector performance. As a result, when blended, biodiesel is only appropriate for usage in cold climates.

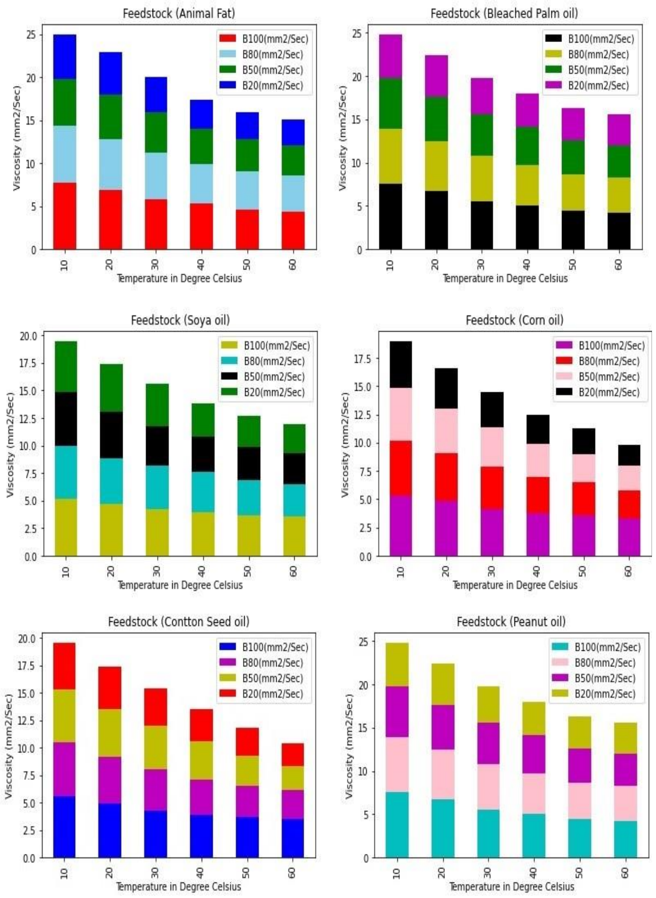

Fig.4 Viscosity Temperature Variation of Biodiesel

3.5 Determination of Biodiesel Flash Point

As can be seen in Fig.5, the biodiesel's flash point was much higher than the 103 ^{o}C minimize the risk of fire outbreaks in the event of accidents by using the ASTM suggested minimum range. Except for B20 of animal fats, which has a flash point of 102 ^{o}C, a little below the range specified, the blend's flash point was also significantly higher than 103 ^{o}C. When comparing the characteristics of the biodiesel and its mix, it is clear that there was hardly any change in the parameters acquired from the biodiesel. This implies that biodiesel made from peanut oil, bleached palm oil, corn oil, soy oil, cottonseed oil can be easily blended with gasoline and diesel while maintaining its quality as an alternative fuel. Flash point is a factor that affects how safely fuel is handled and stored. It is the lowest temperature at which fuel vapors will begin to ignite (Barua, 2011). The flash point is the temperature that must be reached before a fuel can spontaneously ignite in the air and vapors above it.

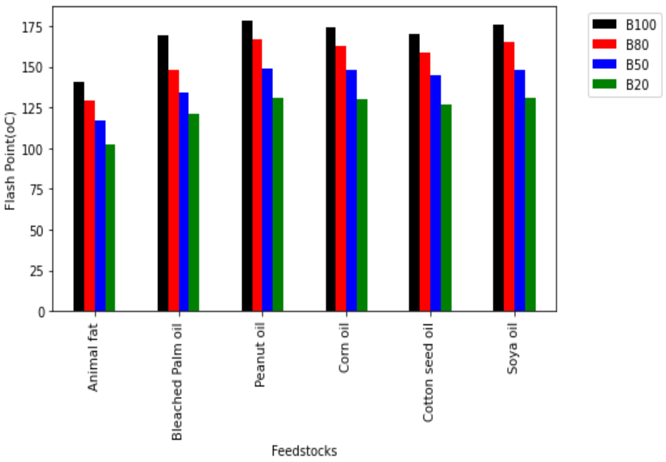

Fig. 5: Flash Point of Biodiesel

3.6 Determination of Biodiesel Cold Weather Properties

The feedstock significantly affects the biodiesel's turbidity and pour point. The lowest turbidity and pour points for B100 corn oil biodiesel among the feedstocks studied are -3 °C and -4 °C, respectively, while the highest turbidity and pour points for animal fat biodiesel are 17 °C and 15 °C, respectively. The B80 cloud point and pour point of biodiesel made from corn oil are both -5 ^{o}C, but those made from animal fat are 13 ^{o}C and 11 ^{o}C, respectively. In comparison to biodiesel made from animal fats, which has a B50 cloud point of 9 ^{o}C and a pour point of 6 °C, biodiesel made from corn oil has a B50 cloud point and pour point of -7 °C. For B20, animal fats and Bleached Palm oil biodiesel have cloud points of 3 °C and 0 °C, respectively, while corn oil biodiesel has a cloud point of -10 °C and a pour point of -12 °C. The biodiesel standard temperature ranges for the B100 cloud point and pour point of each feedstock are respectively -3 °C to 17 °C and -15 °C to 12 °C. This is shown in Fig.6 and 7.

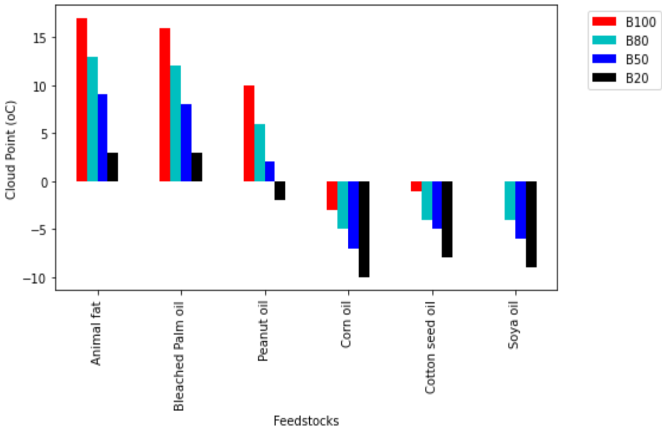

Fig.6: Cloud Point value of biodiesel

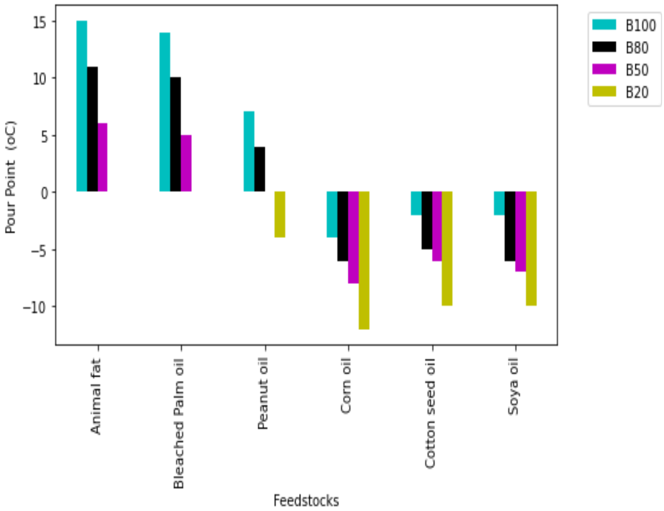

Fig. 7: Pour Point of biodiesel

Poor cold flow properties, especially pour and cloud points, limit the use of biodiesel (Dwivedi and Sharma, 2014a). The long-term use of vegetable oils or their alkyl esters leads to coking of the injector nozzles, heavy engine deposits, filter gumming, sticking of the piston rings and oil thickening due to their poor cold flow properties (Dwivedi and Sharma, 2014b). Long chain saturated fatty acid methyl esters (FAME) and polyunsaturated FAME should both be present in relatively small amounts in biodiesel for it to perform well in low temperature environments and maintain its stability at acceptable standards (Verssimo and Gomes, 2011).

4.0 Discussion

The increased percentage of saturated fatty acids in the animal fat feedstocks led to noticeably lower biodiesel production. As can be seen from the percentage yield results in Fig.1, edible oil (Peanut oil, bleached palm oil, corn oil, cottonseed oil and soybean oil) produced a higher output of biodiesel than non-edible oil (animal fat). Because of its high percentage output, it follows that using edible oil for the creation of biodiesel will result in a food famine. Therefore, despite the poor yield, non-edible oils and fats should be used to produce biodiesel since it is a secondary energy source rather than a primary energy source and also serves as a means of disposing of waste, such as used vegetable oil, used animal fat, etc.

The densities for B100 and all blends of starting materials used in this work are now acceptable based on the ASTM standard range. These levels must be kept within tolerable limits to allow for the optimum air/fuel ratios for complete combustion, as high density biodiesel or its blend can result in incomplete combustion and particulate emissions that can cause environmental pollution. If not, one of the benefits of finding alternative energy sources would be negated. Another property considered in this study is flash point. Higher flash points make biodiesel safer to handle and store (Shahabuddin *et al*., 2103). Flash point is a temperature that represents general flammability in the presence of air. For B100 and the blends, higher flash points were obtained than for petroleum-based diesel. Like previous studies, this one shows that biodiesel has a much higher flash point than petroleum-based diesel. This shows that using biodiesel for transportation is significantly less risky than using petroleum based fuel, as is the risk of fire from storage. The most valuable result is the reduction in total sulfur content of biodiesel and the absence of this component in relation to the reduction of SOX in exhaust emissions, one of the causes of acid rain. Petrodiesel has a sulfur concentration 20-50 times higher than biodiesel. Typically, biodiesel feedstock contains very little sulfur. Sulfur levels appear to have a variety of effects on engine wear and deposits, and these effects are greatly influenced by operating conditions. For environmental reasons, sulfur is restricted to reduce polluting emissions of sulfate and sulfuric acid (Gerpen, *et al*., 2005). Diesel fuel loses much of its lubricity when the sulfur content is reduced. The ability of a fuel to provide lubrication to reduce wear between the moving parts of the diesel injection pump and the fuel injectors is referred to as its lubricity. Biodiesel is practically sulfur-free, but has excellent lubricating properties

The viscosity values obtained for all of the blends were observed to be within the permissible ASTM range of 1.9 to 6.0mm2sec for both diesel and biodiesel at reference temperatures for viscosity (i.e., 40 °C), as shown. However, at 20 ^{o}C, the measured viscosity value is higher than what is advised. This may have an impact on the fuel's fluidity, which results in worse fuel spray atomization and less precise fuel injector performance. This implies that fuel with a high viscosity results in smaller fuel droplets in the engine's combustion chamber, which may not burn as efficiently. This unburned oxidized fuel collects near valves, rings in the engine, piston sidewalls and injector tips. Due to the inadequate fuel spray and poor ignition that occur, greenhouse gases are released. As a result, reliable viscosity measurement is crucial for many product specifications (Hassan and Sani, 2010).

The cloud point and pour point values for cold weather performance are within the recommended range. These values are greater than those for gasoline and diesel, which, respectively, have a pour point of -35 °C to -15 °C and a cloud point of -15 °C to 5 °C. The blends' values were higher than the B100's, indicating that the biodiesel will likely gel at temperatures higher than those of diesel. Because wax crystals can form in either fuel at lower temperatures, consideration should be used while using biodiesel fuels in cold climates. These wax crystals have the potential to clog gasoline filters and harm engines (Kim, 2012; Ghanei, 2014). In cold conditions, it is best to use a biodiesel mix with a lower proportion, such as B20 or B50.

5.0 CONCLUSION

The following conclusions were drawn from this study: Compared to non-edible oils, edible oils provide a higher proportion of biodiesel. Biodiesel and its blends of B20 and higher conform to the ASTM standard range for density. Below room temperature, biodiesel has a higher viscosity than recommended, which can lead to the emission of greenhouse gases. To avoid wax crystals that can clog fuel filters and damage engines, use a lower proportion of B20 or B50 biodiesel blend in cold weather. Compared to petroleum-based diesel, biodiesel has a significantly higher flash point. This demonstrates that compared to petroleum-based diesel, the danger of fire connected with the storage, use, and transportation of biodiesel is significantly reduced. It is essential for the development of fuel from this feedstock to comprehend the fundamental physical features of the manufacture of biodiesel from various feedstocks. The need for energy is essential for human survival. With non-renewable fossil fuels becoming scarcer, several nations are increasingly turning to biofuel technologies to address the issue of steadily rising fuel and energy costs; Most of these biofuels are derived from edible oils. As a result, the food industry's access to cooking oil is at risk. Therefore, to replace edible oil in the production of biodiesel, I propose that more research be done on a variety of viable oil feedstocks.

Conflict of Interest

The authors state that the research was conducted without commercial or financial affiliations that could be considered a potential conflict of interest.

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