IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.311 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 12, Issue 12, December 2025

DOI: 10.17148/IARJSET.2025.121230

Assessment of Fuel Properties of Castor Oil Blend with Kerosene and Ethanol as an Alternative to Petrodiesel

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Abstract: This research work is aimed to develop Castor oil/kerosene blend as alternative to petro-diesel. Castor oil was blended with kerosene and ethanol at different proportions according to extreme vertices mixture design. Density, Cloud point, Color, Aniline point, API gravity, Diesel index, Cetane number, Sulphur content, kinematic viscosity, flash point and fire point of the blends were determined and then statistically analyzed and optimized. The results obtained showed that the flash points of Castor blends 61.18ºF, which implies that, the value of Castor blend is close to the ASTM D 93 standard value for flash point on diesel. The kinematic viscosity for Castor blends was found to be 27.20cst, which indicated that the blends have values near the approved ASTM value for kinematic viscosity. The sulphur content for Castor blends (0.023) were within the accepted range for diesel oil for sulphur content. The values obtained for the cetane number of Castor (30.39) are below the accepted value set by ASTM for diesel oil. When measurements on API gravity of castor blends (34.22) were made, they fell within the accepted range set by motor vehicle manufacturers. The aniline value for Castor blends was found to be 83.05ºF, which are considered to be acceptable. It can therefore be concluded that in this research work it was found that the Castor blends have diesel characteristics.

Keywords: Castor oil, Petro-diesel, Density, Diesel Index, Biofuel

I. INTRODUCTION

Today, 80% of the world energy consumption and almost 100% of energy needed in the transportation sector is met by fossil fuels (Amato *et al.*, 2025). As the population increases the demand for energy to meet the different lifestyles requirements also increases as well. Although fossils fuels are the major energy resources, production and consumption of fossil fuels have caused a lot of environmental damage by increasing the Carbon dioxide (CO_2) concentration in the atmosphere (Laporta M. *et al.*, 2008). Fossil fuels currently provide 80% of the world's energy consumption and nearly all of the energy required for transportation (Amato et al. 2025). The need for energy to meet the demands of various lifestyles grows along with the population. Despite being the primary energy source, the production and use of fossil fuels have greatly harmed the environment by raising the atmospheric concentration of carbon dioxide (CO_2) (Laporta et al. (2010).

The world is presently confronted with twin crises of fossil fuels depletion and pollution which will lead to the scarcity of the oil and environmental degradation. Gasoline and diesel-driven automobiles are the major source of greenhouse gases (GHG) emission. Due to gradual depletion of the world oil reserves (Yaakob Z. *et al* 2013), increasing demand for diesels and uncertainty in their availability (Ramos M. *et al.*, 2009), recent increase in crude oil prices and the dwindling petroleum reserves (Ebenezer, 2010) and the environmental pollution there is an urgent need for alternative and suitable fuels. Alternative fuels promise a harmonious correlation with sustainable development, energy conservation efficiency and environmental preservation. According to the European Biodiesel Board, the EU produced approximately 9 million metric tons of biodiesel in 2009. In 2013 it produced about 65 percent of the world's biodiesel. Other countries like Austria, Belgium, Finland, Italy, Netherlands, Poland and Spain increased their production in 2009 (Azad *et al* 2013). The U.S. uses 62 billion gallons of diesel fuel each year. As the world turned to an alternative, it makes approximately 650 million gallons of soybean oil per year and the production is expected to increase gradually (Yusuf N. N. *et al.*, 2011). The world is currently facing two crises: pollution and the depletion of fossil fuels, which will result in a shortage of oil and environmental deterioration. Cars that run on gasoline or diesel are the main source of greenhouse gas emissions. Owing to the slow depletion of global oil reserves (Akanarama T., 2014), rising diesel demand, and unpredictability in their supply (Deshpande et al. There is a pressing need for appropriate and alternative fuels due to the recent rise in crude oil prices, the depletion of petroleum reserves (Refrat A.A., 2010), and the pollution of the environment. Alternative fuels offer a positive relationship with environmental preservation, energy efficiency, and sustainable development. The European Union produced about 9 million metric tons of biodiesel in 2009, according to the European Biodiesel Board. It produced roughly 65% of the biodiesel produced worldwide in 2013. Austria, Belgium, Finland, Italy, and the Netherlands are among the other nations. Scientists around the world have explored different alternative energy resources which have the potential to quench the ever-increasing energy thirst of the world's growing population. The various bio-fuels energy resources that are explored include biomass, biogas, primary alcohols, vegetable oil, biodiesel, etc to provide a feasible solution to the worldwide fossil fuel crises (Prakash T. *et al.*, 2018). Biofuels have the potentials to create new markets for agricultural products and stimulates rural development because they are generated from crops (Usfa N., 2005). Biodiesel is one of the most valuable forms of renewable energy that can be used directly in existing, unmodified diesel engine (Amato R. *et al*., 2025). It is made from vegetable oil through transesterification. The process involved using an alcohol (e.g. methanol, ethanol or butanol), in the presence of a catalyst, such as sodium hydroxide or potassium hydroxide, to break the molecule of the raw renewable oil chemically into methyl or ethyl esters of the fatty acids, with glycerol as a byproduct (Pinzi S. *et al*., 2018).

Researchers from all over the world have looked into various alternative energy sources that might be able to satisfy the world's expanding population's growing energy needs. To offer a workable solution to the global fossil fuel crisis, a variety of bio-fuels energy resources are investigated, such as biomass, biogas, primary alcohols, vegetable oil, biodiesel, etc. (Demirbas A. 2009). Because biofuels are produced from crops, they have the potential to boost rural development and open up new markets for agricultural products (Prakash T. et al. 2018). One of the most valuable renewable energy sources that can be directly utilized in diesel engines that are already in use and have not been modified is biodiesel (Ramos M. et al., 2009). It is created by transesterification using vegetable oil. The procedure required the use of alcohol (e.g. the g. methanol, ethanol, or butanol), in the presence of a catalyst (such as potassium or sodium hydroxide) to chemically break the raw renewable oil molecule.

Vegetable oil (VO) is among the various sources of energy fuels being considered as alternatives to fossil fuels (Pinzi S. *t al*., 2018). It is a mixture of a number of different esters of fatty acids called triglycerides which are structurally one molecule of glycerol esterified to three molecules of long chain monocarboxylic (fatty) acid. Triglycerides constitute about 10% oxygen by weight. This lowers its heating value by 5 to 8% of that of diesel because oxygen has lower heating value than the carbon and hydrogen (Yusuf N.N *et al.*, 2011). Vegetable oil is produced domestically which helps to reduce costly petroleum product imports. It is biodegradable, nontoxic, contains low aromatics and sulphur and hence, is environment friendly (Yusuf N.N. *et al.*, 2011). The use of SVO leads to reduced engine life, caused by the buildup of carbon deposits inside the engine and the buildup of in the engine lubricant. Diesel engines (DI) with vegetable oils offer acceptable engine performance and emissions for short-term operation but long-term operation results in operational and durability problems. This is because vegetable oils are much more viscous, much more reactive to oxygen, and have higher cloud point and pour point than petro diesel. High fuel viscosity can cause premature wear of the fuel pumps and injectors. It can also dramatically alter the structure of the fuel spray coming out of the injectors to increasing droplet size, decreasing spray angle, and increase spray penetration (Vehicle technologies office, 2014).

Among the many energy fuel sources being explored as fossil fuel substitutes is vegetable oil (VO). Triglycerides are a mixture of several different fatty acid esters that are structurally one molecule of glycerol esterified to three molecules of long chain monocarboxylic (fatty) acid. By weight, triglycerides make up around 10% of oxygen. Because oxygen has a lower heating value than carbon and hydrogen, this reduces its heating value by 5 to 8 percent of that of diesel (Yusuf N.N et al. 2011). Domestic production of vegetable oil contributes to a decrease in the importation of expensive petroleum products. It is environmentally friendly because it is nontoxic, biodegradable, and has low levels of sulfur and aromatics. Because of the accumulation of carbon deposits inside the engine and in the engine lubricant, the use of SVO shortens engine life. Vegetable oil-powered diesel engines (DI) provide acceptable engine performance and emissions.

Because of the accumulation of carbon deposits both inside the engine and in the engine lubricant, the use of SVO shortens engine life. For short-term use, diesel engines (DI) with vegetable oils provide acceptable engine performance and emissions; however, long-term use causes operational and durability issues. This is due to the fact that compared to petroleum diesel, vegetable oils are considerably more viscous, more reactive to oxygen, and have higher cloud and pour points. Fuel pumps and injectors may wear out too quickly due to high fuel viscosity. Additionally, it can significantly change the structure of the fuel spray that emerges from the injectors, increasing spray penetration, decreasing spray angle, and increasing droplet size (Vehicle Technologies Office, 2014).

Therefore, direct vegetable oils use in compression engines, blending is a feasible option for improving some of the properties such as viscosity index, acid value, saponification value and iodine value (Talkit*et al.,* 2012). As no sufficient supply of vegetable oil or plants to completely replace petro diesel, viable method to lower viscosity of vegetable oil (instead of transesterification) is to simply blend it with lower viscosity components such as diesel, kerosene and gasoline to produce the so called “VeggieDiesel”. In doing so, the viscosity of the vegetable oil can be reduced down to an acceptable value for operation in a diesel engine (Yaakob Z. *et al.*, 2014).

As a result, blending vegetable oils is a practical way to improve their viscosity index, acid value, saponification value, and iodine value when used directly in compression engines (Talkitet al. (2012). A practical way to reduce the viscosity of vegetable oil (instead of transesterification) is to simply blend it with lower viscosity components like diesel, kerosene, and gasoline to create the so-called "VeggieDiesel," since there isn't a sufficient supply of vegetable oil or plants to fully replace petro diesel. By doing this, the vegetable oil's viscosity can be lowered to a level that is suitable for use in a diesel engine (Laporta M. et al. (2010).

Several studies have been done to investigate the physical and chemical properties of biodiesel and its blends with petroleum products within and outside Nigeria. In the course of this research work topic ‘experimental modeling of fuel properties of vegetable oil kerosene blends as alternative to petro diesel’, many journals were consulted, which are review here.

According to (Amato R. *et al*. 2025) bio-diesel has been prepared by trans-esterification reaction and without trans-esterification and blend in different proportion with diesel fuel in different proportion of 20%, 30%, 40% and 50%. The properties of the fuel i.e. density, viscosity, dynamic viscosity, carbon residue, flash point, fire point and calorific value of pure mustard oil and its blends have been carried out in the fuel testing laboratory. It has been shown that the variation of fuel properties changes with bio-fuel blends with diesel fuel. They concluded that it can be possible to run diesel engine with biodiesel blends.

The physical and chemical characteristics of biodiesel and its blends with petroleum products have been the subject of numerous investigations both inside and outside of Nigeria. Numerous journals were consulted during the research project "experimental modeling of fuel properties of vegetable oil kerosene blends as alternative to petro diesel," which are reviewed here. Bio-diesel was made using both trans-esterification and non-trans-esterification reactions, and it was blended with diesel fuel in varying amounts (20%, 30%, 40%, and 50%). The fuel's characteristics. The e. The fuel testing laboratory has measured the density, viscosity, dynamic viscosity, carbon residue, flash point, fire point, and calorific value of pure mustard oil and its blends. It has been demonstrated that blending diesel fuel with biofuel alters the fuel's properties. They came to the conclusion that biodiesel blends could be used to power diesel engines.

Prepared biodiesel was used to constitute the biodiesel-diesel blends containing 5%, 10%, 20% and 40% biodiesel (i.e. JB-5, JB-10, JB- 20 and JB-40) volume/volume with base diesel fuel to study their physico-chemical behavior during long term storage. The Kinematic viscosity of all the blends was investigated with and without antioxidant. During oxidation of biodiesel the viscosity increases due to formation of oxidized products which lead to the formation of sediments and gum. The initial kinematic viscosity of neat diesel biodiesel blends (JB5, JB10, JB20 and JB40) ranged from 2.89 to 3.44mm2/s with an average value of 3.10mm^2/s whereas the final value for the same were ranged from 2.95 to 3.617 mm2/s with an average of 3.24 mm^2/s. The density of all the blends was also observed within the range mentioned by standard ASTM-D 445. The initial density range of neat blends (JB5, JB10, JB20 and B40) was found to be 0.8316 gm/cm^{3}e0.8501 gm/cm^3 with an average. Initial density range of 0.838 gm/cm^3 while as the final density value for the same were ranged from 0.8334 gm/cm^{3}e0.8535 gm/ cm^3 with an average of 0.841 gm/cm^3 (Lamporta M. *t al*., 2010).

The biodiesel-diesel blends with 5%, 10%, 20%, and 40% biodiesel were made from prepared biodiesel (i.e. the e. volume/volume with base diesel fuel to examine the physico-chemical behavior of JB-5, JB-10, JB-20, and JB-40 over an extended period of storage. All of the blends' kinematic viscosity was examined both with and without antioxidants. The formation of oxidized products during the oxidation of biodiesel causes the viscosity to increase, resulting in the formation of gum and sediments. Neat diesel biodiesel blends (JB5, JB10, JB20, and JB40) had kinematic viscosities that ranged from 2.89 to 3.44 mm2/s at first, with an average of 3.10 mm2/s, while their final values ranged from 2.95 to 3.617 mm2/s, with an average of 3.24 mm2/s. Every blend's density was found to be within the range specified by standard ASTM-D 445. The average initial density range of neat blends (JB5, JB10, JB20, and B40) was determined to be 0.8316 gm/cm3e0.8501 gm/cm3. 0.83 is the initial density range. Initial density range of 0.838 gm/cm3 while as the final density value for the same were ranged from 0.8334 gm/cm3e0.8535 gm/ cm3 with an average of 0.841 gm/cm3 (Lamporta M. et al., 2008).

II. MATERIALS

Aniline point tester A-212 Rigosha $ Co Ltd, Cloud point machine 94100.3V Stanhope-Seta UK, Flash point tester K14670 Koehler instrument Co., Hydrometer S60/60oF Stevenson UKHydrometer S60/60oF Stevenson UK,Aniline $C_6H_5NH_2$ Merck Absolute. Ethanol C_2H_5OH JHD. Patassium hydroxide KOH JHD,Phenolphthalein BDH. Sodium hydroxide BDH. The solvents used in this research work were of analytical grade and were purchased from local vendors.

III. METHOD

- **Sample Collection**

Sample of Castor oil (*RicinusCommuris)*was collected from National Research Institute for Chemical Technology (NARICT) Zaria, Nigeria. Samples of kerosene and diesel were collected from NNPC approved oil filling stations namely A. A. Rano, U Gostu and S A K Nigeria Limited, Sokoto, Nigeria, in cleaned containers. The physicochemical parameters of the oils and their blends were determined at Nigerian National Petroleum Co-operation (NNPC) Laboratory Kaduna.

- **Experimental Design and Blending**

The experiment was designed using Extreme Vertices Mixture Design on MINITAB 16 statistical Software platform. The effect of three components, namely Vegetable oil, kerosene and ethanol was investigated and optimized to obtain the best blends with similar fuel properties as petrodiesel. The components were set at the following upper and lower levels to obtain a design matrix as shown in the appendix.

Table 1. Upper and Lower Values of the Blends

Components	Code	Lower levels	Upper levels
Vegetable oil	Vegetable oil	5	95
Kerosene	Petro-kerosene	5	95
Ethanol	Ethanol	0	40

- **Physicochemical Analyses**

In this study, some parameters of the diesels, vegetable oil and their blends were determined. The parameters studied in this work and their procedures of determinations are explained below.

3.1 Determination of Aniline Point ASTM D 611

Aniline point (or mixed aniline point) is defined as the temperature at which equal volumes of the sample and aniline form homogeneous mixture. It is use in the characterization of pure hydrocarbons and in the analysis of hydrocarbon mixtures. Aromatic hydrocarbons exhibit the lowest, and paraffin the highest values. Cycloparaffins and olefins exhibit values that lie between those for paraffin and aromatics. In homologous series the aniline points increase with increasing molecular weight. Although it occasionally used in combination with other physical properties in correlative methods for hydrocarbons analysis, the aniline point is the most often use to provide an estimate of the aromatic hydrocarbon content of mixture (Elshafie, 2011).

In this procedure (ASTM D 611) equal amount (10 cm^3) of the sample and aniline was placed in a U tube containing two open terminals. A thermometer was inserted into the sample and bath to read the temperature and the liquids was stirred simultaneously. The mixture was heated gradually to warm the two liquids with stirring until miscibility occurred. The temperature reading at which complete miscibility occurred was recorded as the aniline point of the sample.

The temperature at which equal volumes of the sample and aniline form a homogenous mixture is known as the aniline point (or mixed aniline point). Both the analysis of hydrocarbon mixtures and the characterization of pure hydrocarbons employ it. Paraffin has the highest values, while aromatic hydrocarbons have the lowest. The values of cycloparaffins and olefins fall between those of paraffin and aromatics. The aniline points in homologous series rise as molecular weight increases. The aniline point is most frequently used to estimate the amount of aromatic hydrocarbons in a mixture, though it is sometimes used in conjunction with other physical characteristics in correlative methods for hydrocarbons analysis (Elshafie, 2011). In this process (ASTM D 611), a U tube with two open terminals was filled with an equal volume (10 cm3) of the sample and aniline. The liquids were simultaneously stirred and a thermometer was placed into the sample and bath to measure the temperature.

3.2 Determination of Specific gravity and API Gravity ASTM D 1298

The API gravity was determined by calculation from the specific gravity (SG). Specific gravity is the absolute measure of density of the substance divided by the density of the water at the same temperature. The relative density (specific gravity) was determined at 60/60ºF of the sample according to ASTM D 1298.
The API gravity was calculated from equation 2.1

$$\text{API gravity} = \frac{141.5}{SPGravity} - 131.5 \ldots\ldots 1$$

3.3 Determination of Diesel Index (DI)

The diesel index was calculated from equation 2 below after conversion of the Aniline point into Fahrenheit.

$$\text{Diesel index} = \frac{Anilinepoint \times API}{100} \ldots\ldots 2.$$

3.4 Determination of Cetane Number (CN) ASTM D 613

Perhaps the most important measure of ignition characteristics of diesel and biodiesel fuels is the cetane number, since it directly pertains to ignition within compression ignition engines. The cetane number is the primary specification measurement used to match fuels and engines. It is commonly used by refiners, marketers and engine manufacturers to describe diesel fuels. Nonetheless, cetane number is really a value that is the manifestation of a specific test, ASTM D 613.

The cetane number was calculated from the equation below

$$\text{Cetane number} = DI \times 0.72 + 10 \ldots\ldots 3$$

3.5 Determination of Determination of Cloud Point ASTM D2500

The cloud point is important for low- temperatures applications of fuels. It is the temperature at which a cloud of wax crystals first appear when the fuel is cooled. In general, biodiesel has higher cloud point than diesel fuel. The cloud point of non-edible biodiesel varies significantly with feedstock depending on fatty acid compositions. As the solid phase develops in the liquid bulk, the solution becomes cloudy. With a further decrease in the temperature, the crystal particles grow rapidly and agglomerate, reducing the capacity of the liquid to flow through porous media by plugging the filters, and eventually gel the fluid, preventing it from flowing altogether The cloud point was determined according to ASTM D 2500 using Stanhope-Seta UK machine of model 94100.3V. The machine was on and allowed for 30 minutes to charge. The sample was poured into the test jar to the level mark and closed jar tightly with a wooden cork carrying the thermometer. The position of the cork and the thermometer was adjusted so that the cork fitted tightly. The test jar was placed in a special type refrigerator on the machine and then observed at 3 seconds interval. The test jar was then removed from the refrigerator quickly, inspected for cloud and replaced in not more than 5 seconds. The temperature at which a cloud was induced in the sample caused by the first stage of crystallization was recorded as the cloud point.

3.6 Determination of Color ASTM D 1500

This test method covers the visual determination of the color of a wide variety of petroleum products, vegetable oil and veggie diesel. The procedure below ASTM D 1500 was used in determining the color of pure vegetable oils and their blends. The test tube jar was filled to a depth of at least 50 mm with distilled water and placed in the compartment of the colorimeter through which the standard glasses will be observed. Another jar carrying the sample was placed in the other compartment. Then the container was covered to exclude all exterior light. The light was switch on and color of the sample was compared to that of the standard glasses one after the other until one that matches the color of sample was found.

3.7 Determination of Density ASTM D 1298

Density is a physical property used to calculate the precise volume of fuel necessary to supply an adequate combustion. Therefore, the effect of density in engine operation is very important to injector nozzle. This can influence the efficiency of the fuel atomization for airless combustion systems. It is used in the determination of the viscosity of fuels. It is worth noting that fuel density increases with the increase in the percentage of vegetable oil in the blend. ASTM D 1298 was used in determining the density of pure vegetable oils and their blends. The sample was placed into a clean hydrometer cylinder without splashing to avoid the formation of air bubbles and to reduce to a minimum the evaporation of the lower boiling constituents of the more volatile samples. The cylinder containing the sample was placed in a vertical position in a location free from air current. The appropriate hydrometer was lowered gently into the sample and then released to avoid wetting the stem above the level at which it floats freely. The hydrometer was allowed sufficient time to come to rest and for all air bubbles come to the surface. Then the reading was taken from the hydrometer scale to the nearest one-fifth of a full scale division. The hydrometer was then carefully lifted out immediately after recording the hydrometer scale reading and a thermometer was inserted and stirred the test portion vertically using the liquid-in-glass thermometer as the stirring rod, to ensure uniform temperature and density throughout the hydrometer cylinder. The observed hydrometer scale reading with the observed temperature reading was corrected using the appropriate parts of the petroleum measuring tables.

3.8 Determination of Flash Point ASTM D 93

Flash point is the temperature at which vapors above a given fuel become flammable (Abdulhamid*et al*. 2012). It can also be defined as the temperature at which the oil ignite when exposed to a flame or a spark. It varies inversely with the fuel’s volatility. Generally, biodiesel have higher flash point compared to diesel which is usually around 110°C to180°C while conventional flash point for diesel fuel is only 55–66°C , or in other way the fire hazard associated with transportation, storage and utilization of biodiesel is less than that of petro diesel . The flash point is specified in biofuels to serves as a restriction of the amount of alcohol in biodiesel for safety measures in transportation and storage. It can also be adjusted through blending biodiesel with petro-diesel in appropriate proportions . The biofuels specification for flash point is meant to protect against contamination for highly volatile matters. In general, biodiesel has higher flash point than petro-diesel. ASTM D 93 was used in determining the flash point of pure vegetable oils and their blends. The test cup was filled with the sample until the top of the meniscus is at the filling mark. It was then covered and locating device was also engaged. The thermometer was then inserted and the test flame was ignited and adjusted appropriately. The sample was gradually heated to increase the temperature not less than 5°C or more than 6°C per minute. The stirring device was adjusted at two revolutions per seconds during heating. At every 5°C rise in temperature, the stirring was stopped and the test flame was applied. The flash point was recorded, as the observed reading on the thermometer at the time the test flame cause a distinct flash in the interior of the test cup.

3.9 Determination of Fire Point ASTM D 93

Fire point is the minimum temperature at which the vapors of a fuel catch fire and continue to burn without further heating when contact with a flame. The procedure ASTM D93 was used in determining the fire point of pure vegetable oils and their blends. The test cup was filled with the sample to reach the level mark (at least 75 cm^3) and covered properly and the thermometer was inserted. The heat was applied gradually while stirring in downward direction. After flash point was recorded, the heating of the apparatus was continued until burning was observed and sustained for 5 second after ignition. The temperature at which it occurred was recorded as the fire point.

3.10 Determination of Kinematic Viscosity ASTM D 445

The main purpose of the vegetable oil blends (Veggie diesel) was to reduce the viscosity of the oil. Kinematic viscosity is defined as the resistance of liquid to flow under gravity. It refers to the thickness of the oil and is determined by measuring the amount of time taken for a given oil to pass through an orifice of a specified size. High viscosity may lead to the formation of soot and engine deposits due to insufficient fuel atomization. On the other hand, lower viscosity is easier to pump and achieve final droplets to injector. The viscosity of the fuel increases with chain length (number of carbon atoms). Fuels with high viscosity tend to form larger droplets on injection which can cause poor fuel atomization during the spray. , increases the engine deposits, needs more energy to pump the fuel and wears fuel pump elements and injectors. It is the most critical property as it affects injection behavior. Viscosity of vegetable oil is typically ten times higher than petroleum based diesel. High viscosity leads to a poorer atomization, vaporization and formation of shoots. ASTM D 445 was used in determination of viscosity. The viscometer was charged and placed in a water bath. The charged viscometer was allowed to remain in the bath for 30 minutes until it reached the test temperature (40°C). The volume of the sample was adjusted to the viscometer mark and allows flowing freely. The time (in seconds) required for the meniscus to pass from the first to the second timing mark was recorded. The same operation was repeated two more times (ASTM D 445, 1984). The average result was recorded and kinematic viscosity (V) was calculated from the equation 4

$$V = C \times t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Where t = efflux time in second and C= calibration constant of the viscometer in centistokes per second.

3.11 Determination of Sulphur Content ASTM D 4294

Fuels with high sulfur content have been associated with negative impacts on human health and on the environment, which is the reason for the current tightening of national limits. Vehicles operated on high-sulfur fuels produce more sulfur dioxide and particulate matter. Furthermore, fuels with high sulfur levels may increase engine wear and reduce the efficiency and the life span of oxidation catalytic converters and/or denitrification after-treatment systems. Fuel from vegetable oil are inherently sulfur-free, as only trace amounts of sulfur can be detected from minor components within the feedstock, such as glucosinolates and contamination of protein material. Secondly, it is also possible that when an acid esterified fuel is produced, sulfuric acid can carry over into the final fuel. Due to inherent low sulfur quality, it exhibits tremendous advantages over petrodiesel in terms of sulfur dioxide emissions of which may lead to particle-bound mutagenicity.

The ASTM D 4294 procedure below was used in determining the sulphur content of pure vegetable oils and their blends. The sample was analyzed immediately after pouring into the sample cell and allowing for the escape of the air bubble caused by mixing. The sample cell was placed with the transparent window film facing downwards into the X-ray detector compartment and closed. When the ready menu displayed, the measure key was pressed and the measurement indicator lighted up. Then the measurement started automatically. This can be done in 30 seconds. The measurement results are printed out as well and the ready menu displayed. The out print contains first, second and third reading including their average.

IV. RESULTS

4.1 Response Optimization

Table 2 and 3 below show the response optimizations of the blends. Five different solutions were obtained in attempting to maximize flash point, kinematic viscosity, sulphur content, diesel index, API gravity, aniline Point and cetane number. The result obtained shows that the flash points of all the solutions fall within the ASTM D93 acceptable range. The kinematic viscosity of all the solutions is within the accepted value according to ASTM D 445. All the values obtained for sulphur content are within permissible limit as specified by ASTM D 4294. The values obtained for the cetane number are below the recommended standard set by ASTM D 613. For API gravity, all the solutions fall within the accepted range except solution 5 which is less than the minimum standard (32) according to the ASTM D 611. The optimization further describes that all the solutions are considered to be acceptable for aniline values using ASTM D 611 with the mean value 85.648.

Table 2 and 3: Response Optimization of Selected Parameter

Solution	1	2	3	4	5	Standard	
Castor (cm^3)	45.9091	44.7579	47.5091	47.5091	60.8682	Min	Max
PetroKero(cm^3)	85.9091	94.9783	68.49	68.49	81.5646	×	×
Ethanol(cm^3)	40	0	40	0	20	×	×
Flash P(^{o}F)	76.99	73.73	80.29	80.29	64.01	45	150
Kinematic Viscosity(cst)	29.91	21.86	38.63	38.63	49.96	1.6(cst)	55(cst)
Sulphur	0.016	0.014	0.019	0.019	0.015	×	0.5
Cetane Number	30.86	31.46	29.86	29.86	27.79	51	100
Diesel Index	28.96	29.81	27.58	27.58	24.70		47
API Gravity	34.10	35.35	32.21	32.21	28.82	32	47
Aniline point	85.48	85.04	85.81	85.81	86.11	47	
Composite Desirability	0.73113	0.7183	0.6976	0.6976	0.59817		

Table 3

Parameter	**Castor blend**	**ASTM D975, EN 590 standards**
Aniline Point		60°C to 80°C for diesel fuels
API Gravity		Minimum 40
Specific Gravity		0.82–0.90
Diesel Index		40 to 60+
Cetane Number		Minimum 40n typical range is 48-50
Cloud Point		Varies seasonally and geographically
Color		3.0-3.5
Density		820 kg/m³ and 900 kg/m³ at 15°C
Flash Point		52°C or 60°C
Fire Point		60°C to 70°C
Kinematic Viscosity		Typically specified at 40°C, a common range is 1.9 to 4.1 mm²/s
Sulfur Content		max 10 or 15 ppm (0.0010% or 0.0015%)

V. CONCLUSION

From the result obtained, it can be concluded that castor oil and Jatropha oil if appropriately blended can serve as good alternative to petro diesel. Vegetable oils and kerosene are characterized to be used in the preparation of fuel similar to petrodiesel by blending. However, in the modeling experiment that was statistically anlysed and optimized, Jatropha oil blend were found to have fuel quantity than the castor oil blend. Considering results obtained from the vegetable oil blend with kerosene and ethanol being analysed, the following recommendations are put forward: The samples that fall within the ranges should be further analyzed using engine test for confirmation.

The samples that do not fall within the ranges should not be used in the blending for further analysis. Government and private sector should invest and assist on the cultivation of the castor to encourage petrodiesel production by blending. Further research should be done on castor blend with different petroleum product and different alcohol. Water content by distillation should be carried out for further investigation.

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