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Production and Characterization of Biofuel from Non-Edible Oils: An Alternative Energy Sources to Petrol Diesel

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Additional information is available at the end of the chapter

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1. Introduction

The production and consumption of petroleum oil increases constantly and it has been reported that about 75 million barrels of crude oil is consumed worldwide daily [1-4]. Resulting energy crisis as a result of over dependence on fossil fuel as a source of energy have shown that fossil fuels are limited finite resource and the continuous depreciation of the world oil reserves also corroborates the fact that oil is a finite non-renewable source of energy that will ultimately be exhausted [5-9]. This therefore leads to continuous agitation and research activities towards establishing alternative renewable fuels that can replace and prevent possible negative impacts that may result from continuous use and depreciation of fossil fuel [10]. The need to reduce complete dependence on fossil fuel as a sole energy sources and need to source for alternative energy cannot be over emphasized. Presently, biofuel, biogas and bio ethanol are considered as the most promising alternatives in energy generation that can compete with the fossil fuel [2, 11-12]. Biodiesel is produced in some countries and used efficiently either alone or in blends with minerals diesel in cars and transport vehicles. The transesterification of the triglycerides present in plant oils to the methyl or ethyl esters. Since the passage of the Energy Policy Act of 2005, biodiesel use has been increasing especially in the developed countries. For instance, biodiesel is produced in some countries and used efficiently either alone or in blends with mineral diesel in cars and transport vehicles [13]. The United State Fueling stations make biodiesel readily available to consumers across Europe and increasingly in the USA and Canada. This is an indication that biodiesel can operates in compression ignition engines like petroleum diesel without requiring no essential engine modifications [14-16]. Moreover it can maintain the payload capacity and range of conventional diesel unlike fossil diesel, pure biodiesel is

biodegradable, nontoxic and essentially free of sulphur and aromatics [17-19]. A growing number of transport fleets use it as an additive in their fuel. Biodiesel is being used in both public and private fleet vehicles due to environmentally friendly and the facts that it offers a reduction in some emissions without requiring any modifications to the vehicle of biodiesel [14]. It is worth of mentioning that the production of this alternative energy source (biodiesel), which is a variety of ester-based oxygenated fuels, can be produced from different feedstock, such as vegetable oil, animal fats and non edible oils [20-24]. Hence, the production of biodiesel is sensitive to feedstock; care must therefore take in selecting the feed stock for the production of biofuel [14]. For instance production of biofuel from vegetable oils had been criticized by the experts as a source of food crisis [14]. The critics of this method of biofuel production beliefs that production of biofuel from consumable oil will resulted into food crisis and price instability. Also militate against the commercial availability of biodiesel is the cost of biodiesel. For instance, biodiesel costs over US\$0.5/l compared to US\$0.3/l for petrol diesel, the is due mainly to the cost of virgin vegetable oil used as a feedstock for the production of biodiesel [14]. For instance, in the United State, the cost of soybean is on the average of US\$0.36/l, Currently, the cost of biodiesel stands at 3.83 dollars per gallon which is 19.6% higher compared to that of petro-diesel (\$ 3.07) [25]. It is therefore not surprising that the biodiesel produced from pure soybean is much more expensive than petroleum based diesel. Hence, the recent research and development in the production of biofuel as alternative energy sources that will compete well with the existing energy sources (fossil fuel) is now concentrated on in-edible oil, which is the focus of this present study [26-31]. This work involves comparative study of biodiesel production from *Jatropah curcas* and *Ricinus communis*. The choice of *Jatropha curcas* and *Ricinus communis* as a feedstock for the production of biodiesel is also favoured by the abundantly availability of these plants in Nigeria, despite their abundant availability, they are not properly exploited for technological and material development. Hence, Production of biodiesel from these oils will lead to proper utilization of these vegetable oils. It also includes characterization of both the oils and biodiesel produced. The focus of this study can be achieved through the following objectives;

- Characterization of both *jatropha curcas* and *ricinus commumis* oils to determine density, viscosity, saponification number, iodine value, acid value, peroxide value and moisture content which are compared with the standard.
- Production of biodiesel from *jatropha curcas* and *ricinus commumis* by two-step transesterification reaction.
- Investigation into the effect of temperature and catalyst concentration on the production of biodiesel from oil.
- Characterization of the biodiesel produced to determine the density, flash point, Kinematic viscosity, Cloud point, Sulphur content, Bottom Sediment & Water, Cetane number, water by distillation and distillation properties and compare with that of convention diesel fuel and available standard.
- Comparison of the qualities of biodiesel produced from *Jatropha curcas* and *Ricinus communis* with that of the standard values of biodiesel

1.1. History of biodiesel

The name 'biodiesel' has been given to transesterified vegetable oil to describe its use as a diesel fuel. Transesterification of triglycerides in oils is not a new process. Scientists E. Duffy and J. Patrick conducted it as early as 1853 [11, 32]. Rudolf Diesel's prime model, a single 10 ft (3 m) iron cylinder with a flywheel at its base, ran on its own power for the first time in Augsburg, Germany, on 10 August 1893 running on nothing but peanut oil. In remembrance of this event, 10 August has been declared "International Biodiesel Day". Life for the diesel engine began in 1893 when the famous German inventor Rudolph Diesel published a paper entitled 'the theory and construction of a rational heat engine'. What the paper described was a revolutionary engine in which air would be compressed by a piston to a very high pressure thereby causing a high temperature. Rudolph Diesel designed the original diesel engine to run on vegetable oil [14,32]. Dr Rudolph Diesel used peanut oil to fuel one of his engines at the Paris Exposition of 1900. The engine was constructed for using mineral oil, and was then worked on vegetable oil without any alterations being made. The French Government at the time thought of testing the applicability to power production of the Arachide, or earth-nut, which grows in considerable quantities in their African colonies, and can easily be cultivated there." Diesel himself later conducted related tests and appeared supportive of the idea [32]. Due to the high temperatures created, the engine was able to run a variety of vegetable oil including hemp and peanut oil. At the 1911 World's Fair in Paris, Dr R. Diesel ran his engine on peanut oil and declared 'the diesel engine can be fed with vegetable oils and will help considerably in the development of the agriculture of the countries which use it.' One of the first uses of transesterified vegetable oil was powering heavy-duty vehicles in South Africa before World War II [32]. In a 1912 speech Diesel said, "The use of vegetable oils for engine fuels may seem insignificant today but such oils may become, in the course of time, as important as petroleum and the coal-tar products of the present time." Despite the widespread use of fossil petroleum-derived diesel fuels, interest in vegetable oils as fuels for internal combustion engines was reported in several countries during the 1920s and 1930s and later during World War II. Belgium, France, Italy, the United Kingdom, Portugal, Germany, Brazil, Argentina, Japan and China were reported to have tested and used vegetable oils as diesel fuels during this time [32]. Some operational problems were reported due to the high viscosity of vegetable oils compared to petroleum diesel fuel, which results in poor atomization of the fuel in the fuel spray and often leads to deposits and coking of the injectors, combustion chamber and valves. Attempts to overcome these problems included heating of the vegetable oil, blending it with petroleum-derived diesel fuel or ethanol, pyrolysis and cracking of the oils [14]. Research into the use of transesterified sunflower oil, and refining it to diesel fuel standards, was initiated in South Africa in 1979 [32]. By 1983, the process for producing fuel-quality, engine-tested biodiesel was completed and published internationally. An Austrian company, Gaskoks, obtained the technology from the South African Agricultural Engineers; the company erected the first biodiesel pilot plant in November 1987, and the first industrial-scale plant in April 1989 (with a capacity of 30,000 tons of rapeseed per annum) [32].

Throughout the 1990s, plants were opened in many European countries, including the Czech Republic, Germany and Sweden. France launched local production of biodiesel fuel (referred to as diester) from rapeseed oil, which is mixed into regular diesel fuel at a level of 5%, and into the diesel fuel used by some captive fleets (e.g. public transportation) at a level of 30%. Renault, Peugeot and other manufacturers have certified truck engines for use with up to that level of partial biodiesel; experiments with 50% biodiesel are underway. During the same period, nations in other parts of the world also saw local production of biodiesel starting up: by 1998, the Austrian Biofuels Institute had identified 21 countries with commercial biodiesel projects. 100% Biodiesel is now available at many normal service stations across Europe [32]. In September 2005 Minnesota became the first U.S. state to mandate that all diesel fuel sold in the state contain part biodiesel, requiring a content of at least 2% biodiesel [32]. Today's diesel engines require a clean burning and stable fuel that performs well under the variety of operating condition. Biodiesel is the only alternative fuel that can be used directly in any existing unmodified diesel engine. It has been reported that biodiesel can be blended with the diesel fuel in any proportion due to the similarities in their properties and the current trends in the production of biodiesel from vegetable are now concentrated on non- edible oil as the feedstock. Vegetable oils such as soybean, rapeseed and peanut are edible and expensive though the seeds of these oils are available in large quantities especially in Africa (Tamil Nadu -641 003india) [32]. However, there is need to control their utilization for the production of biodiesel for the purpose of not causing large problem of hunger and deforestation while sourcing for alternative energy sources [33-35].

1.2. Biodiesel

Biodiesel is defined as the mono-alkyl esters of fatty acids derived from a renewable lipid feedstock such as vegetable oils or animal fats [2, 16, 36-37]. In simple terms, biodiesel is the product obtained when a vegetable oil or animal fat is chemically reacted with an alcohol to produce fatty acid alkyl esters. A Catalyst such as sodium or potassium hydroxide is required. Glycerol is produced as a co product. Vegetable oils are a renewable and potentially inexhaustible source of energy with a calorific value close to that of conventional diesel fuel. Their high viscosity, low volatility, incomplete combustion and possibility of formation of deposits are the drawbacks of biodiesel. Biodiesel besides not being refined from crude oil, biodiesel offers other attractive characteristics, such as a significantly lower emission of carbon monoxide, CO (46.7 %,) carbon dioxide, CO₂, (78%), [38], sulphur dioxide, SO₂ and hydrocarbons, HC (45.2%) [39]. It also eliminates the cloud of dense, black smoke normally associated with diesel vehicles and other particulate matter (PM) emissions (66.7%) that cause respiratory damage to a level in line with the Kyoto Protocol Agreement [40]. Biodiesel is also reported to be highly biodegradable in freshwater as well as soil environments. 90–98% of biodiesel is mineralized in 21–28 days under aerobic as well as anaerobic conditions in comparison to 50% and 56% by diesel fuel and gasoline respectively [41]. European tests of rape seed oil-based biodiesel indicate that it is 99.6% biodegradable

within 21 days [42]. Thus within one month of being spilled into the environment, biodiesel should be completely decomposed. This makes biodiesel a good alternative fuel for use in environmentally sensitive areas where fuel leakages and spills would be particularly harmful such as wetland areas and watersheds which supply drinking water. It has been reported also that biodiesels have high cetane number, high flash point and acceptable level of sulphur content which makes it very attractive as an alternative fuel [43]. Reported work by Korbitz (1999) [44] shows that the cetane number of biodiesel fuels is higher than fossil diesel which is considered to be significantly advantageous in terms of engine performance. The flash point of biodiesel fuels is twice as much as that of fossil diesel. Therefore, biodiesel is much safer to store, handle and use than the conventional diesel fuel [45]. Biodiesel fuels have been praised as being sulphur-free and may contain only traces of sulphur emanated from the acidic catalyst used. Also favour the choice of biodiesel as alternative sources of energy is the fact that biodiesel is virtually compatible with commercial diesel engines and practically no engine modifications are required [46]. Biodiesel can also be blended at any level with petroleum diesel to create a biodiesel blend. When blended with fossil diesel, it shows positive synergic effect of biodegradation by means of co-metabolism. For example, the time taken to reach 50% biodegradation of fossil diesel is reduced from 28 to 22 days in 5% biodiesel mixture [47]. In terms of economic benefit, biodiesel production is expected to remain profitable and grow dramatically. Farmers that produce highly rated energy crops such as *Jatropha* for the production of biodiesel stand a chance of improving their income level by providing market outlets for farmers and generate rural employment. The by-product of transesterification reaction, glycerol, when purified can be used in its traditional application (pharmaceutical, cosmetics and food industries). In addition, the obtained glycerol can be used in recently developed applications in the fields of animal feed, carbon feedstock in fermentations, polymers, surfactants and lubricants [48]. Biodiesel, thus, increases the contribution of agriculture to exports and economic growth. It will also generate new industries which will create new jobs and new markets for the majority of unemployed youth [49].

Despite the advantages of biodiesel as perfect alternative energy sources, emission of NO_x is one of the setbacks of biodiesel. The temperature within the cylinders of a vehicle fuelled with biodiesel would increase due to the enhanced combustion as a result of high oxygen content of biodiesel. This increase in temperature stimulates the production of NO_x from the reaction with nitrogen in the air, which results in a small increase in NO_x emission compared to those produced from conventional diesel fuel [50]. Aside from the formation of NO_x by the engine powered with biodiesel, the chemical contents of biodiesel is also a fatty acid methyl ester when the alcohol used during transesterification is methanol or fatty acid ethyl ester in case of ethanol. These ester molecules are susceptible to hydrolytic and oxidization reactions resulting in the formation of polymers. This makes the biodiesel unstable on storage and hence cannot sit on the shelf for long time as it develops mould when it gets old [51]. Exploring the means of producing biodiesel that will compete well with the existing petroleum diesel is of much interest in the recent biodiesel research, especially for those methods concentrating on minimizing the raw material cost. Biodiesel as

alternative energy source can be produced from different sources such as soybean, beef tallow, waste vegetable oil etc depends on the location and availability. The fact that biodiesel burns clearly and source from renewable sources widens its acceptance world wide as alternative energy source. Biodiesel which is described as variety of ester-based oxygenated fuels derived from natural, renewable sources such is a perfect alternative energy sources due to its biodegradability nature. To improve the quality of vegetable oil, researchers have employed different methods listed below to reduce the high viscosity of the oils.

1. Dilution of 25 parts of vegetable oil with 75 parts of diesel fuel (biodiesel blends)
2. Micro emulsions with short chain alcohol (e.g. ethanol or methanol).
3. Thermal decomposition which produces alkanes, alkenes, carboxylic acids and aromatic compounds.
4. Catalytic cracking which produces alkanes, cycloalkanes and alkyl benzene.
5. Transesterification.

Transesterification is described as the best choice as it is relatively simple and produces a product with properties close to diesel fuel. Alcohol, oil and catalyst are combined in an agitated reactor, approx. at 60°C during 1h. Smaller plants often use batch mode reactors, but larger plants use continuous flows processes involving continuous stirred-tank reactors or plug flow reactors. The processes involved in biodiesel production from feedstock containing low levels of FFA which, include soybean oil, canola (rapeseed) oil, and the higher grades of waste restaurant oils. Alcohol, catalyst, and oil are combined in a reactor and agitated for 1hour at 60°C. Smaller plants often use batch reactors [32] but most larger plants (4 million L/yr) use continuous flow processes involving continuous stirred-tank reactors (CSTR) or plug flow reactors [32]. The reaction is sometimes done in two steps in which 80% of the alcohol and catalyst is added to the oil in a first-stage CSTR. Then, the product stream from this reactor goes through a glycerol removal step before entering a second CSTR. The remaining 20% of the alcohol and catalyst is added in this second reactor. This system provides a very complete reaction with the potential of using less alcohol than single-step systems. After the reaction, glycerol is removed from the methyl esters. Due to the low solubility of glycerol in the esters, this separation generally occurs quickly and can be accomplished with either a settling tank or a centrifuge. The excess methanol tends to act as a solubilizer and can slow the separation. However, this excess methanol is usually not removed from the reaction stream until after the glycerol and methyl esters are separated due to concern about reversing the transesterification reaction. Water may be added to the reaction mixture after the transesterification is complete to improve the separation of glycerol [32]. After separation from the glycerol, the methyl ester enter a neutralization step and then pass through a methanol stripper, usually a vacuum flash process or a falling film evaporator, before water washing. Acid is added to the biodiesel product to neutralize any residual catalyst and to split any soap that may have formed during the reaction. Soaps will then react with the acid to form water-soluble salts and FFA. The salts will be removed during the water washing step and the FFA will stay in the biodiesel. The water washing step is intended to remove any remaining catalyst, soap, salts, methanol, or free glycerol

from the biodiesel. Neutralization before washing reduces the amount of water required and minimizes the potential for emulsions to form when the wash water is added to the biodiesel. After the wash process, any remaining water is removed from the biodiesel by a vacuum flash process. The glycerol stream leaving the separator is only 50% glycerol. It contains some of the excess methanol and most of the catalyst and soap. In this form, the glycerol has little value and disposal may be difficult. The methanol content requires the glycerol to be treated as hazardous waste. The first step in refining the glycerol is usually to add acid to split the soaps into FFA and salts. The FFA is not soluble in the glycerol and will rise to the top where they can be removed and recycled[32]. Mittelbach and Koncar [32] described a process for esterifying these FFA and then returning them to the transesterification reaction stream. The salts remain with the glycerol, although depending on the chemical compounds present, some may precipitate out. One frequently touted option is to use potassium hydroxide as the reaction catalyst and phosphoric acid for neutralization so that the salt formed is potassium phosphate, which can be used for fertilizer. After acidulation and separation of the FFA, the methanol in the glycerol is removed by a vacuum flash process, or another type of evaporator. At this point, the glycerol should have a purity of 85% and is typically sold to a glycerol refiner. The glycerol refining process takes the purity up to 99.5–99.7% using vacuum distillation or ion exchange processes. Therefore, biodiesel is defined as the mono-alkyl esters of fatty acids derived from vegetable oils, animal fats by transesterification with alcohol in the presence of catalyst. A catalyst such as sodium or potassium hydroxide is required; glycerol is produced as a by-product.

2. *Jatropha curcas* and *ricininus communis* (castor oil) and biodiesel production

2.1. *Jatropha curcas*

Jatropha is a drought resistance tree that can be grown in areas where rainfall is as low as 500-600mm. It does well in Cape Verde where rainfall is only 250mm but the air is humid. In dry season, it tends to shed its leaves. Where rainfall is high above 1000mm, it does better in hot rather than temperate climate. *Jatropha* grow in soils that are quite infertile. It is usually found at lower elevations (below 500m) (14,32]. *Jatropha Curcas* is mostly found in northern part of Nigeria e.g. Sokoto, Zamfara, Kebbi, Kastina Minna etc [32].

There is growing interest for biodiesel production from non-edible oil source, like *Jatropha curcas*. *Jatropha curcas* is a plant belonging to Euphorbiaceae family, which is a non-edible oil-bearing plant widespread in arid, semi-arid and tropical regions of the world[32]. *Jatropha curcas* has an estimated annual production potential of 200 thousand metric tons in India and can grow in waste land [32]. *Jatropha curcas* is native to Mesoamerica but has been distributed worldwide since the XVI century by Spaniards and Portuguese to their tropical and subtropical colonies in Africa and Asia. In India and other countries of the Far East, villagers used *Jatropha curcas* as a hedge crop, and the extracted seed oil to make soap

or fuel for lamps. In Europe, biodiesel production is based on the methyl ester of rapeseed oil, while in the United States, the methyl esters of soybean and rapeseed oils are more used. In tropical countries, *Jatropha curcas* seed oil is being promoted for biodiesel production, and the technology has been optimized [51]. It was found that the shell could be for combustion, hull/husk for gasification, and cake for production of biogas, spent slurry as manure, oil and biodiesel (made from *Jatropha* oil) for running CI engines. The kernels) of *jatropha curcas* have about 50% oil. The oil recovery in mechanical expeller was about 85%, while more than 95% recovery of oil could be achieved when extracted by solvent method. The biodiesel from *jatropha curcas* oil has a great potential due to its comparable properties to diesel, such as calorific value and cetane number [51]. Therefore, many researchers have shown great interest in using *Jatropha* oil to produce biodiesel. Azam *et al.* (2005) [52] found FAME of *Jatropha curcas* were most suitable for use as biodiesel and it met the major specification of biodiesel standards of USA, Germany and European Standard Organization. Sarin *et al.* (2007) [51] made 25 appropriate blends of *Jatropha* and palm biodiesel to improve oxidation stability and low temperature property based on the fact that *Jatropha* biodiesel has good low temperature property and palm biodiesel has good oxidative stability. It was found that antioxidant dosage could be reduced by 80-90% when palm oil biodiesel is blended with *Jatropha* biodiesel at about 20-40%. This techno-economic combination could be an optimum mix for Asian Energy Security. Tiwari *et al.* (2007) [53] used response surface methodology to optimize three important reaction variables, including methanol quantity, acid concentration, and reaction time. The optimum combination for reducing the FFA of *Jatropha* oil from 14% to less than 1% was found to be 1.43% v/v sulfuric acid catalyst, 0.28 v/v methanol-to-oil ratio and 88 min reaction time at 60°C for producing biodiesel. The properties of *Jatropha* oil biodiesel conformed to the American and European standards. As comparison, Berchmans *et al.* (2008) [54] developed a two-step pretreatment process in which the high FFA (15%) of *Jatropha curcas* seed oil was reduced to less than 1%. In the first step, the reaction was carried out with 0.60 w/w methanol-to-oil ratio in the presence of 1 wt.% sulfuric acid as an acid catalyst in 1h at 50°C. In the second step, the transesterification reaction was performed using 0.24 w/w methanol-to-oil ratio and 1.4 wt.% sodium hydroxide as alkaline catalyst to produce biodiesel at 65°C. The final biodiesel yield of 90% in 2hours was reported. As well as experimental study, theoretical studies of reaction mechanism were also conducted regarding to base-catalyzed transesterification of the glycerides of the *Jatropha* oil (Tapanes, Aranda, Carneiro & Antunes, 2008). In that study, semi-empirical AM1 molecular orbital calculations were used to investigate the reaction pathways of base, catalyzed transesterification of glycerides of palmitic, oleic and linoleic acid. The researchers concluded that the reaction mechanism included three steps: Step 1- Nucleophilic attack of the alkoxide anion on the carbonyl group of the glyceride to form a tetrahedral intermediate. Step 2-Breaking of the tetrahedral intermediate to form the alkyl ester and the glyceride anion. Step 3-Regeneration of the active catalyst, which may start another catalytic cycle. This study suggested that the Step 2, decomposition of the tetrahedral intermediate, determined the rate of base-catalyzed

transesterification of glycerides. A lot of different approaches were taken when producing biodiesel from *Jatropha* oil. In addition to conventional methods, preparation of biodiesel from *Jatropha* oil using ultrasonic energy was investigated (Kachhwaha, Maji, Faran, Gupta, Ramchandran & Kumar, 2006). Low frequency ultrasound (33 kHz) was applied to transesterify *Jatropha oil* with methanol in the presence of base catalyst at 6:1 methanol/oil molar ratio. The reaction time (about 15-30 min) was much shorter than conventional mechanical stirring method. This method was proved to be efficient and economically functional. Moreover, enzyme catalysts were also utilized for biodiesel production from *Jatropha oil*. Shah *et al.* *Jatropha* oil in presence of supercritical carbon dioxide. The optimum conditions were found to be 8h, 45°C, 5:1 molar ratio of alcohol to oil and an enzyme loading of 30% based on the weight of oil. However, conversions of only 60-70% were obtained even after 8 hours. The authors attributed this to the fact that the enzymatic reaction encountered both substrate and product inhibition. In contrast, when synthesis of biodiesel in supercritical alcohols, high conversions (80%) were obtained within 10 min and nearly complete conversions were obtained within 40 min. Despite of expected high operating cost due to high temperature and pressure associated with supercritical alcohol, it was still considered to be economically feasible since the reaction time was very short [32]. Furthermore, the absence of pre-treatment step, soap removal, and catalyst removal can significantly reduce the capital cost of a biodiesel plant. Meanwhile, many researches were conducted aiming at evaluating the performance, emission, and combustion characteristics in a diesel engine for *Jatropha* oil and *Jatropha* oil biodiesel [32]. Haldar *et al.* (2008) [55] found that *Jatropha* oil gave the best results related to the performance and emissions, such as CO, CO₂, HC, smoke and particulates, at high loads and 45° before Top Dead Center (BTDC) injection timing when compared with non-edible straight vegetable oils of Putranjiva, *Jatropha* and Karanja. Though received a booming interest due to its general characteristics and potentiality was recommended by some researchers that better data are urgently needed to guide investment since uncertainty do exist, based on the fact that *Jatropha curcas* is still a wild plant which exhibits a lot of variability in yield, oil content and oil quality [32].

2.2. *Ricinus communis* (castor oil)

Castor oil is possibly the plant oil industry's most underappreciated asset. It is one of the most versatile of plant oils, being used in over ten diverse industries. Owing to its unique chemical structure, castor oil can be used as the starting material for producing a wide range of end-products such as biodiesel, lubricants and greases, coatings, personal care and detergent, surfactants, oleo chemicals e.t.c. Compared to many other crops, castor crop requires relatively fewer inputs such as water, fertilizers and pesticides. The crop can also be grown on marginal land, thus providing an excellent opportunity for many regions of the world to utilize their land resources more productively [32]. The plant prefers well-drained moisture relative clay or sandy loan in full sun requires a rich soil and day time temperature above 20°C for seedling to grow well. Castor is native to tropical Africa but it grows widely

in Nigeria as weed it can be found in Borno, Sokoto, Jos, Zaria and so many other places in the country [32]. Though, it has been reported that the plants is not properly exploited, however a fiber for making ropes can be obtained from its stem. The growing plant is said to repel flies and mosquitoes when grown in the garden and it is also said to rid it of moles and nibbling insect, while the leaves have insecticidal properties.

Cultivation of castor plants for the production of biodiesel started in 2008 in the Waletia and Goma Gofa regions of Ethiopia, the initiative is run by energy company (Global energy Ethiopia) who are also conducting research and development program to create new varieties of castor with better yields(sub-sahara Africa gateway, science and development network, 2008). Castor oil contains a number of fatty acids similar to those in cooking oils such as oleic, palmitic acids e.t.c. However, among vegetable oils castor oil is distinguished by its high content of ricinoleic acid (about 89.5 %). Castor oil unsaturated bond, molecular weight (298), low melting point (5 °C) makes it industrially useful. Castor oil is unique among all fats and oils, it has an unusual composition of a triglyceride of fatty acids, and it is the only source of an 18-carbon hydroxylated fatty acid with one double bond (Aldrich, 2003). The chemical composition of castor oil is given below [32]:

- Ricinoleic acid - 89.5 %
- Linoleic acid - 4.2 %
- Oleic acid - 3 %
- Stearic acid - 1 %
- Palmitic acid - 1 %
- Dihydroxystearic acid - 0.7 %
- Exosanoic acid - 0.3 %

Biodiesel derived from castor oil rates high among other oils with ash content of about 0.02 %, sulfur content less than 0.04 %, negligible potassium content, 35 GJ/T which compares favorably with other vegetable oils and petro diesel of about 45 GJ/T, and viscosity that is much higher than petro diesel, but this major bottleneck of the viscosity can be considerably reduced by transesterification making it a very efficient source of biodiesel

3. Material and methodology

3.1. Material and equipment

This study focus on the conversion of oil from *Jatropha Curcas* and *Ricinus communis* (castor oil) into biodiesel by means of esterification. The entire chemicals used in this study are of analytical grade (98-99.5%). They include Carbon tetra chloride (Analar, BDH), Wij's solution (Mixture of glacial acetate, iodine trichloride and carbon tetrachloride) (Hopkins and Williams, London), potassium hydroxide solution (Analar, BDH), potassium hydroxide pellet (Burgoyne & co, India), petroleum ether (Analar, BDH), potassium iodide solution (M&B, England), sodium thiosulphate (M&B, England), hydrochloric acid (Analar, BDH) and potassium iodide pellet (M&B, England). The equipments used are pH meter,

distillation apparatus, viscometer, thermostatic hot plate, sulphur in oil analyzer, magnetic stirrer, digital weighing balance, thermometer, petri dish, pippete, separating funnel, burette, oil test centrifuge, pycometer bottles, Abbe refractometer, flash point tester, oven and aneline point teseter.

3.2. Methodology

3.2.1. Physical and chemical characterization of the oil

Prior to the production of biodiesel from jatropha cacus and risininus communis (castor oil), various anlysis such as specific gravity, acid value, free fatty acid, saponification value, iodine value, peroxide value, viscosity, moisture content and refarctive index were conducted on the oil samples.

3.2.1.1. Determination of specific gravity

A 50ml pycometer was washed thoroughly with detergent, water and petroleum ether, it was then dried and weighed. The bottle was filled with water and weighed, the bottle was then dried and filled with the oil sample and weighed, from theory, and the density of a substance was equal to mass of a substance per unit volume of that substance.

3.2.1.2. Determination of Acid Value/Free Fatty Acid (FFA)

2g of the oil was measured and poured in a beaker. A neutral solvent (a mixture of petroleum ether and ethanol) was prepared and 50ml of it was taken and poured into the beaker containing the oil sample. The mixture was stirred vigorously for 30minutes. 0.56g of potassium hydroxide (KOH) pellet was measured and placed in a separate beaker and 0.1M KOH was prepared, 3drops of phenolphthalein indicator was added to the sample and was titrated against 0.1M KOH till the color change observed turned pink and persisted for 15minutes.

$$AV = \frac{56.1 \times V \times N}{W_{oil}} \quad (1)$$

Where; V= volume of standard alkali used; N= normality of standard alkali used; W_{oil}= weight of oil used

$$FFA = \frac{AN}{2} \quad (2)$$

3.2.1.3. Determination of saponification value

The alcoholic KOH was freshly prepared by dissolving KOH pellet in ethanol. 2g of oil was measured and poured into a conical flask. 25ml of the alcoholic KOH was added to it, a blank was used. The sample was well covered and placed in a steam water bath for 30minutes shaking it periodically, 1ml of phenolphthalein was added to the mixture and titrated against 0.5M HCl to get the end point.

$$SV = \frac{5.61 \times (B-A) \times N}{W_{OIL}} \quad (3)$$

Where; B= volume of standard ethanol potassium hydroxide used in blank titration; A= volume of standard ethanol potassium hydroxide used in titration with the oil; N= normality of standard acid; W_{oil} = weight of oil used.

3.2.1.4. Determination of iodine value

The oil was poured into a small beaker, a small rod was added to it. 2g of the oil was weighed and poured into a glass-stopper bottle of about 250 ml capacity. 10ml of carbon tetrachloride was added to the oil to dissolve. 20ml of Wij's solution was added and a stopper was inserted and allowed to stay in the dark for 30 minutes. 15ml of potassium iodide solution (10%) and 100ml of water was introduced and the mixture was thoroughly mixed and titrated with 0.1M sodium thiosulphate solution using starch as indicator (titration = 'A' ml). A blank was carried out at the same time starting with 10ml of carbon tetrachloride (titration = 'B' ml)

$$IV = \frac{0.1269 \times (B-A) \times N \times 100}{W_{OIL}} \quad (4)$$

B= volume of sodium thiosulphate used in blank titration.

A= volume of sodium thiosulphate used in titration with oil.

N= normality of sodium thiosulphate.

W_{oil} = weight of oil used.

3.2.1.5. Determination of peroxide value

1g of oil was weighed into a clean drying boiling tube, 1g of powdered potassium iodide and 20ml of solvent mixture (2 volume of glacial acetic acid + 1 volume of chloroform) was added, the tube was placed in boiling water so that the liquid boils within 30 seconds and was also allowed to boil vigorously for not more than 30 seconds. The content was quickly poured into a flask containing 20ml of potassium iodide solution; the tube was washed out with 25ml of distilled water and was titrated with 0.002M sodium thiosulphate solution using starch as indicator. A blank was also carried out at the same time.

3.2.1.6. Determination of viscosity

A viscometer was used to determine the viscosity of the oil. Chloroform was poured first in the viscometer and the time at which the chloroform reached the bottom of the equipment was taken. The oil was then poured into the viscometer and the time taken for the groundnut oil to reach the bottom of the equipment was taken and recorded in mm^2/s

3.2.1.7. Determination of moisture content

In order to determine the moisture content in the oil (%), 48.15g of oil was weighed in a moisture pan, the weight of the pan and oil was taken and was put inside an oven for 3 hours at a temperature of 45°C . After every 1 hour, the sample was cooled and weighed until the weight before and after was approximately equal.

3.2.1.8. Determination of refractive index

Abbe's refractometer was used to determine the moisture content of the oil sample, the equipment was well cleaned with cotton wool and placed in a bright room for light. The refractometer was calibrated using distilled water then small sample of the oil was placed on it and the refractive index observed was taken and recorded.

3.2.2. Two-step transesterification of the crude oils

In order to avoid the problem of saponification, a two-step method was used for synthesis of biodiesel from *Jatropha curcas* and *Ricinus communis*.

3.2.2.1. Acid catalyzed esterification

This is considered as a pre-treatment for the crude oils in order to reduce their water content which is the main cause of soap formation and subsequently, reduce its FFA. The oil was heated in the reaction glass tube to 65°C and a solution of concentrated H₂SO₄ acid (1.0% based on the oil weight) in methanol (30% v/v) was heated to 45°C and added to the reaction glass tubes. The resulting mixture was stirred on a magnetic stirrer for 1hr and the content was poured into a separating funnel and allowed to settle for 2 hours. The methanol-water fraction at the top layer was removed and the oil was decanted to be used for transesterification reaction.

3.2.2.2. Alkali catalyzed transesterification

50ml of oil was measured and poured into a 150ml conical flask and heated to a temperature of 45°C using a water bath. A solution of sodium methoxide was prepared in a 250ml beaker using 0.25g of NaOH pellet and 10.5mls of anhydrous methanol. The solution was properly stirred until the NaOH pellet was completely dissolved in it. The sodium methoxide solution was then poured into the warm oil and stirred vigorously for 90minutes using a magnetic stirrer and the mixture was left to settle for 24hours in a separating funnel. After settling, the upper layer which was biodiesel was decanted into a separate beaker while the lower layer which comprises of glycerol and soap was collected from the bottom of the funnel. The quantity of biodiesel collected was measured and recorded.

3.2.3. Washing

Biodiesel must be washed to remove any remaining methanol, glycerin, catalyst, soaps and other impurities. Water used is warmed to about 45°C and is passed through the esters to allow soluble material, excess catalyst and other impurities to stick to the water and be settled to the bottom of the vessel. The water is removed from the vessel periodically until the wash water drained out is clear or the pH of the biodiesel becomes relatively neutral.

3.2.4. Drying

The biodiesel washing sometimes leaves the biodiesel looking a bit cloudy. This means there's still a little water in it. It was heated slowly to 100°C and held there until all moisture present was evaporated i.e. dry.

3.2.5. Characterization of the biodiesel produced

3.2.5.1. Determination of specific gravity/density (ASTM D1298) by hydrometer method

This procedure is used to measure of specific gravity of the biodiesels. A clean dry empty 50ml density bottle is to be weighed and the mass recorded as M , it is then filled up with distilled water and subsequently with the samples. The mass of the bottle and water is taken and recorded as M_1 and that of biodiesel as M_2 respectively hence, the specific gravity is evaluated. This procedure is used to determine the specific gravity of the sample.

3.2.5.2. Determination of flash point: ASTM D 93 — Flash-point by Pensky-Martens closed cup tester

A sample of the biodiesel is heated in a close vessel and ignited. When the sample burns, the temperature is recorded; the pensky-martens cup tester measures the lowest temperature at which application of the test flame causes the vapor above the sample to ignite. The biodiesel is placed in a cup in such quantity as to just touch the prescribed mark on the interior of the cup. The cover is then fitted onto the position on the cup and Bunsen burner is used to supply heat to the apparatus at a rate of about 5°C per minute. During heating, the oil is constantly stirred. As the oil approaches its flashing, the injector burner is lighted and injected into the oil container after every 12 second intervals until a distinct flash is observed within the container. The temperature at which the flash occurred is then recorded, it is repeated three times and the average taken.

3.2.5.3. Determination of cloud point (ASTM D 2500)

A sample of the biodiesel is placed in a test jar to a mark and then placed inside a cooling bath. The temperature at the bottom of the test jar that is the temperature at which the biodiesel starts to form cloud is taken as the cloud point.

3.2.5.4. Determination of kinematic viscosity (ASTM D 445)

A viscometer is inserted into a water bath with a set temperature and left for 30minutes. The sample is added to the viscometer and allowed to remain in the bath as long as it reaches the test thermometer. The sample is allowed to flow freely and the time required for the meniscus to pass from the first to the second timing mark is taken using a stop watch. The procedure is repeated a number of times and the average value are taken which is then multiplied with the viscometer calibration to give the kinematic viscosity.

3.2.5.5. Determination of pour point (ASTM D 97)

A sample of the biodiesel is kept in the freezer to about 50°C then placed in a heating mantle to melt. The temperature at the bottom of the test jar that is the temperature at which the biodiesel starts to pour is taken as the pour point.

3.2.5.6. Cetane Number (ASTM D 613)

Cetane Number is a measure of the fuel's ignition delay. Higher Cetane numbers indicate shorter times between the injection of the fuel and its ignition. Higher numbers have been

associated with reduced engine roughness and with lower starting temperatures for engines.

3.2.5.7. Acid Number (ASTM D 664)

The biodiesel sample is measured and poured in a beaker. A neutral solvent (a mixture of petroleum ether and ethanol) is prepared and 50ml of it is taken and poured into the beaker containing the biodiesel. The mixture is stirred vigorously for 30 minutes. 0.56g of potassium hydroxide (KOH) pellet is measured and placed in a separate beaker and 0.1M KOH is prepared, 3 drops of phenolphthalein indicator is added to the sample and is titrated against 0.1M KOH till the color change observed turned pink.

3.2.5.8. Determination of sulphur content (ASTM D 5453)

The sulphur content was determined by the energy dispersive X-ray fluorescence spectroscopy technique. The biodiesel was placed in disposable plate covered with male and female cells; the sample was placed in a oil in sulphur test equipment and left for 10 minutes. The equipment measures the sulphur content of the biodiesel three (3) consecutive times and takes the average which is then recorded as the sulphur content.

3.2.5.9. Determination of distillation characteristics (ASTM D 86)

The distillation characteristics were studied using distillation apparatus (Model PMD 100) in accordance to the procedure in **ASTM D 86**. 100ml of the biodiesel was charged into the distillation flask. A thermometer provided with a snug-fitting cork was tightly fitted into the neck of the distillation flask. The flask was then fixed tightly into the condenser tube by raising and adjusting the flask support board of a calibrated distillation batch unit. Systematic observations and recordings of temperature readings at 5mls, 10mls, 20mls, 30mls, 40mls, 50mls, 60mls, 70mls, 80mls, and 90mls respectively, and volumes of condensate were taken and recorded.

3.2.5.10. Determination of bottom water and sediment (ASTM D 2709)

The water and sediment test was determined according to **ASTM D 2709**, 50mls of the biodiesel and 50ml of toluene were mixed in a 100ml centrifuge tube with the tube tip having graduation of 0.01ml over the range of 0 to 0.2ml, the centrifuge tube was shaken so that an even distribution of the mixture is observed. The tube was placed in a trunnion cup inside an oil test centrifuge in such a way that the tubes are placed opposite each other to establish a balance in the centrifuge. The centrifuge is then closed and timed for 30 minutes; the samples are then whirled for agitation at a speed of 1800rpm to ensure homogeneity. The combined water and sediment at the bottom of the tube was reported to the nearest 0.005ml.

4. Results and discussion of results

Concern on the situation of fossil fuel as the sole sources of energy and environmental pollution emanated from the utilization of fossil fuel resulted into considerable attention

given to alternative sources of energy. Biodiesel is considered as a perfect alternative source of energy that can compete with fossil fuel in terms of performance and efficiency. However, production of biodiesel from vegetable oils and animal fats also raised a serious concern of food crisis and the critics of the production of biodiesel from edible are making it difficult to justify the use of edible oil for fuel, considering the tremendously increment in demand for edible oil. Hence the need to produce biodiesel from non-edible oils such as *Jatropha Curcas* and *Ricinus Communis* oil that are grown in large quantities and waste lands in Nigeria, which is the focus of this study. Results obtained on characterization of the oils and biodiesel produced from the non-edible oils are hereby presented.

4.1. Physiochemical properties of *Jatropha curcas* and *Ricinus communis* oil

Ricinus communis and *Jatropha Curcas* oils that were utilised as a feedstock in the production of biodiesel were characterized to determine their physiochemical properties such as density, pH, viscosity, acid value, iodine value etc. The results obtained on the properties of oils were compared with that of American Oil Chemists' Society (AOCS) standard values and the results obtained are presented in Table 1. The iodine value shows the level of unsaturation of the oil and also influences the oxidation and deposition formed in diesel engines. It is used in determining the drying property of the oil. Iodine value obtained for both *Jatropha curcas* and *Ricinus communis* were seen to be 98gI₂/100g and 85gI₂/100g respectively and both values fall within the acceptable AOCS limit as shown in Table 1. The iodine value of *Jatropha* (98 gI₂/100g) was seen to be higher than that of *Ricinus* (85 gI₂/100g) and this signifies that there is a higher degree of unstauration in the former than in the latter, although, both oils are classified as non-drying oils since their iodine value is below 115 gI₂/100g. Moisture in vegetable oils is a great impediment to the formation of esters due to increase in tendency of soap formation and thus will have to be minimal for transesterification to occur [14]. The moisture content in both *Jatropha curcas* and *Ricinus communis* were seen to be 0.20% and 0.24% respectively and are within the range specified by AOCS as shown in Table 4.0. The moisture content of *Jatropha curcas* (0.20%) was seen to be a little less than that of *Ricinus communis* (0.24%) and this signifies a higher content of water in *Ricinus communis* than *Jatropha curcas*. The saponification value of oil is a measure of the tendency of the oil to form soap during the transesterification reaction. The saponification value obtained for *Jatropha curcas* and *Ricinus communis* were seen to be 190mgKOH/g and 178mgKOH/g respectively and are within the range specified by AOCS as shown in Table 1. The saponification value of *Jatropha curcas* (190mgKOH/g) was seen to be a bit higher than that of *Ricinus communis* and this thus signifies a higher tendency of the former forming soap during transesterification reaction than the latter. Vegetable oils with high acid value are classified as inedible while those with low acid value are classified as edible oils. The acid value obtained for both *Jatropha curcas* and *Ricinus communis* were seen to be 36.8mgKOH/g and 0.913mgKOH/g respectively and both values fall within the acceptable AOCS limit as shown in Table 1. Leung and Guo (2006) [56] reported that oils with high acid value tend to deactivate catalyst used during transesterification and the acid value of *Jatropha* (36.8mgKOH/g) was seen to be exceedingly higher than that of *Ricinus*

(0.913mgKOH/g) and this signifies that the ester yield of *Jatropha curcas* will be less than that of *Ricinus communis* due to increase catalyst deactivation and soap formation in the former. Also, the same can be said for the free fatty acid (FFA) present in both with their values being 18.4% and 0.457% respectively. Kinematic viscosity which is a measure of the flow capabilities of the oils was measured at 30°C. The kinematic viscosity of *Jatropha curcas* and *Ricinus communis* were seen to be 51.8mm²/s and 6.9mm²/s respectively and both are within the range specified by AOCS as shown in Table 1. The kinematic viscosity of *Jatropha curcas* (51.8mm²/s) was seen to be extremely higher than that of *Ricinus communis* (6.9mm²/s) and this means that *Ricinus communis* has a higher flow capability than *Jatropha curcas* and can easily undergo transesterification.

Parameters	Unit	Obtained Expt Value for <i>Jatropha Curcas</i>	Obtained Expt Value for <i>Ricinus Communis</i>	AOCS Standard Value for <i>Jatropha Curcas</i>	AOCS Standard Value for <i>Ricinus Communis</i>
Saponification Value (S.V)	mgKOH/g	190	178	188-195	176-184
Iodine Value (I.V)	gI ₂ /100g oil	98	85	84-100	83-88
Acid Value (A.V)	mgKOH/g	36.8	0.913	1.0-38.2	2.0 max
Free Fatty Acid (FFA)	%	18.4	0.457	<1%	<1%
Specific Gravity (S.G) at 30 °C	-	0.913	0.89	0.910-0.915	0.88-0.915
Density (ρ)	g/ml		0.856	-	-
Refractive Index (R.I) at 30 °C	-	1.466	1.468	1.467-1.470	1.467-1.470
Kinematic Viscosity (ν) at 30 °C	mm ² /s	51.8	6.9	-	6.3-8.9
Moisture Content	%	0.20	0.24	-	0.355 % max

Table 1. Comparison of Physiochemical Properties of *Ricinus communis* and *Jatropha curcas* oils with AOCS standard values

4.2. Optimization of two-step transesterification of *Jatropha curcas* and *Ricinus communis*

Transesterification is the reaction between triglycerides and lower alcohols to produce free glycerols and the fatty acid ester. It involves reaction between the oil which is the feedstock

and an alcohol, usually methanol in the presence of a catalyst such as sodium or potassium hydroxide to give corresponding esters. Although, the main factors influences the transesterification reactions are the alcohol to oil molar ratio, catalyst type and concentration, reaction temperature and reaction time, with the methanol to oil ratio higher than stoichiometric ratio to drive the equilibrium to a maximum ester yields. However, in this present study all other factors are kept constant except the temperatures that are varying between 50°C to 60°C. Sodium hydroxide was selected as the catalyst, the ratio of oil to methanol was 1:6, reaction time was 60 minutes and the weight of catalyst was 0.5wt%. Results obtained on the effect of temperature on the yield of biodiesel from *Jatropha Curcas* and *Ricinus Communis* oil as the feed stock are presented in Table 2. The best yields were obtained for both the methyl ester of *Jatropha curcas* and *Ricinus communis* at the temperature of 60°C with the percentage methyl ester yield being 96% and 98%. This is because at 60°C, the molecules of the triglycerides of *Jatropha curcas* and *Ricinus communis* had high kinetic energy and this thus increased the collision rate and therefore, improved the overall process by favouring the formation of methyl esters while at the lower temperatures of 50°C and 55°C with corresponding percentage methyl ester yield of 86% and 90% and 92% and 95% respectively, there was lesser collision of reacting molecules and thus, reduced biodiesel yield as seen in Table 2. The reason for this behaviour is due to the endothermic nature of the reaction. The higher reaction temperature would favour endothermic reaction, thus increasing the rate of reaction as well as the ester concentration. Although at 65°C, it was noticed that there was a drop in percentage methyl ester yield for both *Jatropha curcas* and *Ricinus communis* as shown in Fig 4.0 below with their corresponding values being 84% and 86% respectively. This is because at the reaction temperature (65°C), there was increased vaporization of the alcohol (methanol) used in the transesterification process due to the proximity of the reaction temperature (65°C) to the boiling point of methanol (64.7°C). Based on the results obtained on the effect of temperature on the yield of biodiesel, it can be deduced that the optimum conditions for the production of methyl ester from crude *Jatropha curcas* and *Ricinus communis* through two-stage transesterification are oil to methanol molar ratio of 1:6, catalyst concentration of 0.5wt%, reaction time of 60 minutes and reaction temperature of 60°C.

Temperature (°C)	<i>Jatropha curcas</i> Production Yield (wt%)	<i>Jatropha curcas</i> Methyl Ester Yield (wt%)	<i>Ricinus communis</i> Production Yield (wt%)	<i>Ricinus communis</i> Methyl Ester Yield (wt%)
50	89	86	93	90
55	94	92	98	95
60	99	96	99	98
65	90	84	92	86

Table 2. Effect of Temperature on Biodiesel Yield from *Jatropha curcas* and *Ricinus communis*

4.3. Characterization of produced esters

The biodiesel produced from *Jatropha curcas* and *Ricinus communis* using the optimal conditions of 1:6 oil to methanol molar ratio, 0.5wt% catalyst concentration, 60 minutes

reaction time and reaction temperature of 60°C were analyzed for their fuel properties. Their properties were compared to the ASTM D 6751 biodiesel standard and the ASTM D 975 fossil diesel standard in order to confirm their acceptability as fuel in diesel engines as shown in Table 3. Kinematic viscosity is a measure of resistance to flow of a liquid due to internal friction of one part of the fluid moving over another. High viscosity affects the atomization of a fuel upon injection into the combustion chamber and thus leads to the formation of engine deposits [57]. The kinematic viscosities of *Jatropha curcas* and *Ricinus communis* were determined to be 4.93mm²/s and 14.2mm²/s respectively and when compared to ASTM D 6571, it was seen that the viscosity of *Jatropha* falls within range while that of *Ricinus communis* is far from the acceptable standard, although, it falls within the acceptable limit of fossil diesel (ASTM D 975) as presented in Table 3. It can be therefore said that the methyl esters of *Ricinus communis* has a higher tendency of forming deposits in engines than that of *Jatropha curcas* due to the significant difference in kinematic viscosity and this makes *Jatropha curcas* methyl ester a more suitable fuel as regards viscous property. The flash point is the lowest temperature at which an applied ignition source will cause the vapours of the fuel to ignite. It is therefore a measure of tendency of a sample to form a flammable mixture with air. The flash point obtained for *Jatropha curcas* and *Ricinus communis* were 142°F and 150°F respectively and they fall within the range of standard limit set by ASTM D 6751 (130°F min) [58]. *Ricinus communis* has a higher flash point when compared to *Jatropha curcas*, but both are considerably high and this leads to their safer handling and storage. Cloud point and pour point have implications on the use of biodiesel in cold weather applications. The cloud point is the most common measure of the tendency of a fuel to crystallize and the cloud point of *Jatropha curcas* and *Ricinus communis* were determined as 5°C and 8°C respectively. This signifies that *Ricinus communis* has a high tendency of forming cloudy crystals easily in cold temperature than *Jatropha curcas*.

Biodiesel is also potentially subject to hydrolytic degradation caused by the presence of water. Fuel contaminated with water can cause engine corrosion and breakdown. From the results obtained, *Jatropha* has traces of bottom sediment and water while *Ricinus communis* has 0.05%vol and both values conforms to the ASTM D 6751 set standard whose maximum allowable limit is 0.05%vol. Since *Jatropha curcas* methyl ester has a negligible amount of bottom water and sediment, it is of better quality compared to *Ricinus communis*. Sulfur in the atmosphere has negative impacts on human health and on the environment and biodiesel have traditionally been acknowledged as sulfur-free which is of great advantage over fossil diesel and the results obtained confirms that fact. The sulfur content of both *Jatropha curcas* and *Ricinus communis* were 0.05%wt and 0.03%wt which is within the ASTM D 6751 standard limit (0.05 max). Also, the sulphur content of the methyl ester of *Jatropha* was seen to be higher than that of *Ricinus* and this signifies that the latter is more environmentally friendly than the former. Elevated total glycerine values are indicators of incomplete esterification reactions and predictors of excessive carbon deposits in the engine. This can be as a result of incomplete washing of the ester after production. The free glycerine is a source of carbon deposits in the engine because of incomplete combustion. The free and total glycerines determined for the methyl ester of *Jatropha curcas* and *Ricinus communis* were 0.02wt% and 0.24wt% and 0.02wt% and 0.23wt% respectively and both values were seen to be within the acceptable standard of ASTM D 6751. On comparison with

each other, they were found to be approximately equal. Generally, the cetane number is a dimensionless descriptor of the ignition quality of a diesel fuel. As such, it is a prime indicator of diesel fuel quality. The cetane number of the methyl esters of *Jatropha curcas* and *Ricinus communis* were found to be 46.11 and 50.64 respectively. On comparison with standard, it was found that the cetane number of that of *Jatropha curcas* was below the allowable minimum of 47 stated by ASTM D 6751 while that of *Ricinus communis* was slightly above it. On further comparison with fossil diesel standard, it was seen that the centane number of both was above the allowable minimum of 40 imposed by ASTM D 975. Thus results confirm the fact that biodiesels generally, have a higher cetane number than fossil diesels

Property	Unit	ASTM Test Method	Expt. Value for <i>Jatropha curcas</i>	Expt. Value for <i>Ricinus communis</i>	ASTM Standard for Biodiesel (ASTM D 6751)	ASTM Standard for Petrol diesel (ASTM D 975)
Kinematic Viscosity at 40°C	mm ² /s	D 445	4.39	5.42	1.9-6.0	1.9-4.1
Density/Specific Gravity	kg/l	D 1298	0.88	0.88	0.86-0.89	0.95 max
Flash Point	°F	D 93	142.0	150.0	93.0 min	150 min
Cloud Point	°F	D 2600	41.0	46.4		40 max
Total Sulphur (X-Ray)	% wt	D 4294	0.05	0.03	0.05max	0.50 max
Bottom Water & Sediment	% vol	D 1796	Trace	0.05	0.05 max	0.50 max
Distillation Properties IBP	°C	D 86	128	302	360 max	-
FBP	°C		329	360		205 max
Total Recovery	%		98	97		
Centane Number	-	D 975	46.11	50.64	47 min	40 min
Water by Distillation	% vol	D 95	Trace	0.05	-	0.5 max
Free Glycerine	% mass	D 6584	0.02	0.02	0.02 max	0.02 max
Total Glycerine	% mass	D 6584	0.24	0.23	0.24 max	0.24 max

Table 3. Fuel Properties of *Jatropha curcas* and *Ricinus communis* Methyl Esters

Boiling point is the temperature at which a liquid transition to a gas and it is also related to the flash point. For a pure substance the boiling point is a single temperature value.

However, for a mixture of hydrocarbons as existing in biodiesel fuel, there is a range of boiling points for the different constituent chemical specie. The data tested for in the methyl ester of *Jatropha curcas* and *Ricinus communis* includes the initial boiling point (IBP), boiling temperature corresponding to increments of the volume of fuel distilled (10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% and 90%), final boiling point (FBP) and % total recovery (Table 4) .

Percentage Recovery (cm ³)	Temperature (°C)	
	<i>Jatropha curcas</i>	<i>Ricinus communis</i>
IBP	128	302
10%	234	307
20%	255	309
30%	260	312
40%	290	322
50%	313	330
60%	321	336
70%	326	343
80%	328	350
90%	329	360
FBP	329	362
% Total Recovery	97.77	97.00

Table 4. Distillation Characteristic Table of *Jatropha curcas* and *Ricinus communis* Methyl Esters

5. Conclusion

The need to move away from oil as a major source of energy is growing every year, due to the price instability and environmental pollution which are the consequence of over dependence on the fossil fuel. The current research and development on alternative energy that will replace fossil fuel is now focusing on the biofuel. Renewable biofuel will reduce the dependence on oil and also reduce the trade deficit of nations, especially the developing nations. However, for biofuel to compete with the fossil fuel and possibility replacing it as the energy source, needs to be easy, cheap and fast to produce. Production of biofuel from vegetable oil is however not economical due to the fact that production of biodiesel from vegetable will lead to food crisis while trying to solve energy crisis. It is therefore much more desirable to use non-edible oils as a feedstock in the production of biodiesel, which is the focus of this study. This study report the production of biodiesel from non-edible oils (*Jatropha Carcus* and *Ricinus Communis*) as alternative to petrol diesel. Based on the results of experimental analysis, it can be concluded that oils from both feed stocks are suitable for the production of biodiesel. Also, temperature had a high effect on biodiesel yield and the yield increased with increasing temperature up to a point where the reacting temperature was proximal to the boiling point of the methanol. It can also be concluded that, though, *Ricinus communis* had a higher methyl ester yield (98wt%) than *Jatropha Carcus* (96wt%) at

same optimal reaction conditions, the methyl ester of *Jatropha Carcus* is a more suitable fuel for diesel engines than that of *Ricinus communis* because the fuel properties obtained for the former were more compatible with the engines and in accordance with ASTM D 6751 than that of the latter.

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