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# Evaluation of Different Materials for Biodiesel Production

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***Abstract- The challenges of the dwindling supply of fossil fuels and environmental pollutions caused by them are of growing concerns in the world today. Theincrease in world population has resulted in higher consumption of fossil fuel leading to a reduction in petroleum reserves,which are finite and found only in a few regions of the world. Hence, it becomes necessary to look for alternative fuel that is cheap and can be produced from readily available materials. Biodiesel is a renewable energy derived from vegetable oil and animal fats by transesterificationwith methanol and is widely adopted in many countries around the world as an alternative form of energy resource. It has been found to be a very good substitute for petroleum diesel with several advantages such as lower toxicity, higher flash and fire points than the petroleum diesel meaning that they are less flammable hence they are safer to handle, better biodegradable and higher lubricity than the petroleum diesel which means that an engine run on biodiesel will be less prone to wear and will last longer. The high cost of biodiesel is a major setback to its commercialization. And is mainly due to the high cost of raw materialsit's the production. Therefore, identifying the right and readily available material that will give good biodiesel yield with good fuel properties and performance dynamic efficiency is very important. This Paperevaluates the different materials that are suitable for biodiesel production as an alternative source of fuel.***

***Keywords: Alternative fuel, Biodiesel, Petroleum fuel, Transesterification, Triglycerides***

## I. INTRODUCTION

With the increase in world population, there has been a steady increase in world energy demand and it is estimated that by 2030 the world energy demand as measured in quadrillion BTU will double [14]. This increase will mostly be for fossil fuels as fossil fuels make up 86% of the world's energy supply [14]. Much of the world's energy requirements depend on petrochemical sources, coal, and natural gases; however, these resources are limited and have environmental concerns like air pollution and global warming. Thus, the search for an alternative energy sources has become very necessary.Also, fossil fuels are finite and based on current projections; the world's fossil fuel supply would be exhausted 72 years from the present [12].

In addition to the need to provide a renewable source of energy, there is also the need to ensure that these renewable energy sources are environmentally friendly. Burning of fossil fuels has been associated with emission of large quantities of greenhouse gases and global warming [14]. Biomass is a viable renewable energy source that has been utilized in various forms for the supply of energy, one of these energy products from biomass is biodiesel. Biodiesel is a renewable energy that is widely adopted in many countries around the world as an alternative form of energy resource. It has been found to be a very good substitute for petroleum diesel [33]. Other advantages of biodiesel over fossil fule are lower toxicity, higher flash point, better biodegradability and higher lubricity [3 ,8,15]. The high cost of biodiesel is a major setback to its commercialization [21, 28]. This high cost of biodiesel is mainly due to the cost of raw materials for the production [18]. Although the literature covers a wide variety of materials available for bio-fuel; ranging from animal fats and nuts to edible and non-edible oils, systematic assessment with respect to the essential properties of these materials has not been reported thus far. Therefore, this paper aims to assess these materials based on their availability, fuel properties, and production yield and performance dynamic efficiency.

## II. INFORMATION AND ANALYSIS

### 2.1 Sources of Biodiesel

Crops like rapeseed, soybean, mustard, flax, sunflower, canola, palm oil, hemp, *and Jatropha curcas*have become vital sources of alternative fuels in diesel engines. Other important sources are waste vegetable oils and animal fats. Rudolf Diesel initially designed his engine with coal dust in 1893. Consequently, he designed his engine with vegetable oil in order to attract farmers to own engine with available fuel. Vegetable oils have sparkling lubrication possessions; they do not have sulfur content, and offer no storage difficulty. In addition, vegetable oils yielding trees absorb more carbon dioxide from the atmosphere during their photosynthesis than they add to the atmosphere on burning [29].

Generally, vegetable oils consists of five main acids which are: palmitic (hexadecanoic), stearic (octadecanoic), oleic (9z-octadecenoic), linoleic (9z, 12z-octadecadienoic), and linolenic (9z, 12z, 15z-octadecatrienoic) acids. Geography and climate have played an active role in biodiesel production. Therefore, palm oil dominated in tropical countries, rapeseed/canola oil is primarily used in Europe, and soybean oil and animal fats are mostly used in the United State [23].

There are two types of vegetable oils; edible and non-edible oils. Edible oils are the major sources to produce biodiesel fuel like sunflower, soybean, and palm oils [24]. Due to higher prices of edible vegetable oils compared to diesel fuel, waste vegetable oils and non-edible crude vegetable oils are now being used as biodiesel sources [27]. Raw materials for vegetable oil production for biodiesel have the following advantages such as: liquid in nature, portability, availability, renewability, higher heat value (about 88% of no.2 diesel fuel), lower sulfur content, biodegradability.There are disadvantages to such as:

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higher viscosity, lower volatility, the reactivity of unsaturated hydrocarbon chains.

Due to these disadvantages , vegetable oils are not used directly as biodiesel, so there are methods to enhance the vegetable oil's characteristics for biodiesel production [10]. Trans-esterification with methanol can be deemed as a main method used to get biodiesel fuel. The transesterification of soybean oil using Calcium Oxide (CaO) as a solid base catalyst to convert soybean oil to renewable fuel was studied by [19]. In addition, [31] used CaO/mesoporous silica catalyst with transesterification of soybean oil to produce biodieselThe availability and cheap price of waste cooking oils makes biodiesel competitive in price with petroleum fuel. In China, with annual consumption of edible oils approaching 22 million tons, the country generates more than 4.5 million tons of used oil and grease each year, only half of this quantity is used to produce biodiesel fuel [22, 26].Soybean oil is consumed widely and it's extracted from soybean seed. Soybean contains a considerable quantity of carbohydrate for ethanol production. Jatropha curcas is a tree planted to protect crops from animals. It grows on infertile land; it can withstand severe conditions and can be cultivated as a part of the approach for reclaiming the spoiled lands [32]. Advantages of crude *Jatropha curcas* seed oil nominated it as a biodiesel form. High free fattyacid level of Jatropha should be reduced to enhance biodiesel production [5].

Palm oil is another type of renewable source for biodiesel fuel. In 1982, Malaysia started to use palm oil as an alternative to petroleum fuels, an extensive palm oil based program utilized to develop production technology to produce biodiesel fuel [17].

## 2.2 Techniques for Biodiesel Production

To date, various techniques have been developed and used for the transesterification of triglycerides to fatty acid esters. Most of these techniques are similar, requiring the use of methanol for the transesterification of oils and fat with or without a catalyst and differences amongst these techniques are based on the type of catalyst that is being employed.

The earliest technique, which however is still widely used and most preferred for the home processing of biodiesel is thehomogenous alkali-catalyzed technique. This technique involves the use of an alkaline catalyst to catalyze the conversion of triglycerides to methyl esters. The most commonly Used alkaline catalysts are sodium hydroxide (NaOH), potassium hydroxide (KOH), however studies show that sodium methoxide and potassium methoxide are more powerful catalysts. Sodium hydroxide and potassium hydroxide, commonly known as caustic soda and caustic potash, are most preferred because they are cheap, easy to obtain and they can produce an almost complete transesterification of triglycerides to methyl esters. These catalysts are classified as homogenous because they dissolve into the reaction mixture. The alkali-catalyzed technique is very sensitive to high fatty acid and water content of the feedstock/starting oil and is deactivated in the presence of a fatty acid and water composition more than 1% and 0.06% of the starting oil respectively. The homogenous acid-catalyzed technique has also been used for the transesterification of triglycerides and it is favorable for low quality feedstock, like the waste vegetable oil, with a high FFA and water content. The acid catalyst is not deactivated in the presence of FFA and the FFA is converted directly to methyl esters. However, the acid catalysts are more corrosive than the alkali one and are a bit more hazardous to use. More so, the acid-catalyzed transesterification of triglyceride is a very slow one. Homogenous acid catalysts that have been used include sulphuric acid, sulphonic acid, p-toluene sulphonic acid, phosphoric acid and hydrochloric acid.

Another technique, which involves the use of an acid-catalyzed pretreatment of feedstock followed by an alkali-catalyzed transesterification, has been found to be more favorable than the acid-catalyzed when dealing with low quality oils with high FFA and water content. Research has proved that this acid-alkali technique overcomes the problems of corrosion and waste of time associated with the acid-catalyzed technique and produces a high conversion rate of triglycerides. The acid in this technique reduces the FFA and water content of the feedstock to levels suitable for the alkali-catalyzed reaction. Even though this technique seemed favorable for low quality oils and fats, it still had a setback, which is associated with all homogenous catalysts that have been used; this setback is the difficulty in separation of residual catalyst. With homogenous catalyst, the catalysts dissolve into the reaction mixture and require separation from the reaction products. At this point comes in the efficiency of heterogeneous catalyzed techniques. The heterogeneous catalyzed techniques differ from the homogenous techniques because the catalysts employed do not dissolve into the reaction and are easily separated by filtration. Most of the heterogeneous catalysts that have been developed are less reactive than their homogenous counterparts and more research is still being done to develop more reactive heterogeneous catalyst. Some of the heterogeneous catalyst that has been experimented are potassium carbonate, magnesium oxide, calcium oxide, carbonates of basic and acidic macro reticula organic resins, alkane alumina and Lewis acids.

Other techniques for the transesterification of triglycerides to methyl esters are the lipase-catalyzed technique and the non-catalyzed technique. The non-catalyzed technique involves the use of supercritical alcohol without any catalyst while the lipase-catalyzed-technique uses lipase as a catalyst. Both techniques have proven to be superior to the acid and alkali techniques however; they are expensive and can increase the price of biodiesel, which is already higher than the petroleum diesel

## 2.3The Biodiesel Production Process

There are quite a number of steps involved in the processing of biodiesel; the steps actually depend on the type of oil and technique that is used. The processing of fresh oil for instance is less complicated than that for waste and recycled oil. The waste oil requires a few more pretreatment steps before it can be conveniently used for the production of biodiesel. Even when using fresh oil, there are still some variations depending on the free fatty acid content of the oil and the production technique being used. For clarity purposes, all steps in the production of biodiesel have been categorized into three groups; the Pretreatment of oil, the biodiesel Production reaction and the Separation and purification of biodiesel and by products.

## 2.4Pretreatment of Oil

Waste and recycled oil contain considerable amount of solid particles, FFA and water, which if not removed will interfere with the methyl ester chemical reaction. Solid particles are can very easily be removed using appropriate filtration methods. Filtration removes particles that can cause the oil to hold water; hence, making the separation of water will be more difficult. Published laboratory works have reported a number of ways by which solid particles can be removed from waste oil for biodiesel production. [25] Reported the filtration of oil through glass wool while hot, settling at 25$^{O}$C for several weeks, decantation and filtration through no. 4 filter paper for removal of solid particles and foreign bodies in the oil. [11] Centrifuged and filtered the waste oil to remove food bits and preheated to 395K (121$^{O}$C) to remove unwanted moisture content. [9]Reported a more vigorous method of purification ofwaste oil. In their work, Chen et al initially filtered at reduced pressure, stirred with $H_3PO_4$ and equiponderant water successively, followed by settling and decantation in a separating funnel. Finally the oil was stirred with activated clay to remove discoloration. So far, no published work that has compared the effects of these separation techniques on the quality of oil and biodiesel produced has been found. However, it is agreeable that these methods reduce solid particles to allowable limits.

On the other hand, the FFA content of biodiesel starting oils is a bit more difficult to handle. Methods that have been used to reduce the FFA content of waste oils are acid pretreatment with alcohol, steam injection, column chromatography, neutralization and film vacuum evaporation. The high FFA content of waste and recycled oils makes the use of an alkaline catalyst less effective for these oils resulting in a batch of soapy jelly-like product. Thus, the acid pretreatment is most commonly used for these oils. The acid pretreatment reduces the FFA to levels that are suitable for the alkaline reaction. One method that has been employed by home processors of biodiesel to reduce the FFA content of starting oil is the use of glycerin treatment. Glycerin is a byproduct of biodiesel production and for home processors; it is not likely that they will have any good use for the glycerin produced. The quantity of glycerin produced may also not be sufficient to sell to industrial users. In this event, the glycerin is used to pre-wash the oil.

### 2.5 The Biodiesel Production Reaction

The preferred biodiesel reaction technique for home processor is the homogeneous base catalyzed reaction that utilizes a liquid base/alkaline catalyst for the reaction. This technique is preferred because the NaOH and KOH catalyst are easier to get and cheaper to use. More so, this technique is able to produce a very high conversion rate and faster reaction time. Heterogeneous catalysts are another alternative for the production of biodiesel. Heterogeneous catalysts can be easily separated from the biodiesel by filtration and they may be recycled. In addition, heterogeneous catalyst may eliminate the need for water washing of biodiesel, as the catalyst is not dissolved in the biodiesel. In general, heterogeneous base catalysts are more active and less corrosive than the heterogeneous acid catalysts and are more favored for biodiesel transesterification reaction. Base heterogeneous catalysts that have been studied include mixed oxide of zinc and aluminum [7], calcium methoxide [20], calcium oxide, Na/NaOH/$\gamma$-$Al_2O_3$, Alumina-supported potassium iodide, and many more.

The problem with many heterogeneous catalysts is that they require high temperatures and pressures to produce a good activity [13]. High temperatures and pressures are however not safe for use in home processing. More so high temperatures and pressures translate to higher equipment cost and higher total production costs.

### 2.6 Post Treatment of Biodiesel Produced

Unrefined biodiesel from biodiesel production usually contains impurities like unreacted reactants and some by products, which are unfavorable to the use of biodiesel in the engine. Thus, it is very important to remove these impurities before the biodiesel can be used in the engine. The first step in biodiesel refining has been usually separated from glycerol by gravity settling and decantation. Glycerol and biodiesel are two immiscible liquids and if left to settle will form two distinct liquid layers. After settling, biodiesel can be easily separated from glycerol by decantation. Biodiesel is usually left for at least one hour before it is extracted. Excess methanol in the biodiesel stream is usually separated by distillation and all other residues are separated by washing the biodiesel with water.

## III. INFORMATION AND ANALYSIS

### *3.1 Properties of Oil*

The vegetable oils that are used for the production of biodiesel have some fuel related properties. Some of these properties are found in table 1 [1, 2, 4, 16, and 30]

**Table1.Oil properties.**

| **Properties** | **Units** | **Jatropha oil** | **Palm oil** | **Soybean oil** | **Waste cooking oil** |
|---|---|---|---|---|---|
| **Kinematic viscosity at 38$^o$C** | Mm$^2$/s | 49.93 | 39.6 | 32.6 | 36.4 |
| **Cetane No** | $^o$C | 40-45 | 42.0 | 37.9 | 49.0 |
| **Heating value** | Mj/kg | - | - | 39.6 | - |
| **Flash point** | $^o$C | 240 | 267 | 254 | 485 |
| **Cloud point** | $^o$C | - | 31.0 | - | - |
| **Density** | Kg/ml | 0.9186 | 0.9180 | 0.9138 | 0.8830 |
| **Carbon residue** | (wt %) | 0.10 | 0.23 | 0.25 | 0.46 |

**Table 2. Some Chemical Properties of Oils**

| Properties | Units | Jatropha oil | Palm oil | Soybean oil | Waste cooking oil |
|---|---|---|---|---|---|
| Saponification value | Mg KOH/g | 185.0 | 208-214 | - | 188.2 |
| Iodine value | g Iodine/100 g oil | 25.2 | 37.0 | 130 | 141.5 |
| Acid value | Mg KOH/oil | 10.58 | 207-213 | 0.20 | 0.28 |
| Free fatty acid value | % | 5.29 | 5.30 | - | 1.32 |

**Table 3. Fatty acid distribution of the Oils (% by wt)**

| S/N | Fatty acid | Jatropha oil | Soybean oil | Waste cooking oil | Palm oil |
|---|---|---|---|---|---|
| 1. | Myristic | 0.1 | 0.1 | 4.7-14.5 | 15.6 |
| 2. | Palmitic | 14.1-15.3 | 11.4 | 16.0 | 44.3 |
| 3. | Stearic | 3.7-9.8 | 3.2 | 5.2 | 4.6 |
| 4. | Arachidic | 0.3 | 0.2 | 52.9-65.8 | - |
| 5. | Behenic | 0.2 | 0.3-2.4 | 15.4-20.7 | - |
| 6 | Palmitoleic | 1.3 | 0.1-1.0 | 4.8-8.8 | - |
| 7 | Oleic | 34.3-45.8 | 21.8 | 34.3 | 38.7 |
| 8 | Linoleic | 29-44.2 | 54.9 | 40.8 | 10.5 |

### 3.2 Fuel Properties of Biodiesel (as compared to Petroleum Diesel)

The properties of biodiesel are close to diesel fuels. Biodiesel is characterized by determining its viscosity, density, cetane number, cloud and pour points, characteristics of distillation, flash and combustion points, higher heating value, etc[34].

### 3.2.1 Viscosity

The viscosity of a liquid is a measure of its resistance to flow; this is a very important property of a diesel fuelbecause it affects the engine fuel injection system predominantly at low temperatures. A highly viscous fuel will result in poor atomization hence a loss of power of the engine and production of smoke. As shown in the table 1, biodieselis slightly viscous but their viscosities are still close to that of the petroleum diesel. This is an advantage of biodiesel over its source oils[6].

### 3.2.2 Density

The density of diesel fuels is another important property of the fuels that affects the fuel injection system, density is usually measured at 15°C. Density of biodiesel is the weight of a unit volume of fluid while the specific gravity is the ratio of the density of a liquid to the density of water. The fuel injection equipment meters the fuel volumetrically and high densities translate into a high consumption of the fuel. From table 1, it can be seen that biodieselhas densities between 0.860g/cm$^3$ and 0.897g/cm$^3$ at 15°C which is higher than that of the petroleum diesel, however this high density can be said to make up for the low volumetric energy content of biodiesel.

### 3.2.3 Cetane Number

The cetane number of a fuel is a measure of the ignition quality of the fuel, the higher the cetane number the better the ignition quality. Flow; this is a very important property of a diesel fuel Standards for biodiesel[11]. On the basis of ignition quality, biodiesel can be said to be betterthan the petroleum diesel because they have cetanenumbers higher than that of the petroleum diesel, this high cetane number is due to higher oxygen contents. This means that they will burn smoothly and with less noise in a diesel engine than petroleum diesel.

### 3.2.4 Flash and Fire points

Biodiesel's have higher flash and fire points than the petroleum diesel meaning that they are less flammable hence they are safer to handle. However, biodiesel has worse oxidation stability than petroleum diesel and will deteriorate under prolonged storage due to oxidation in the presence of air.

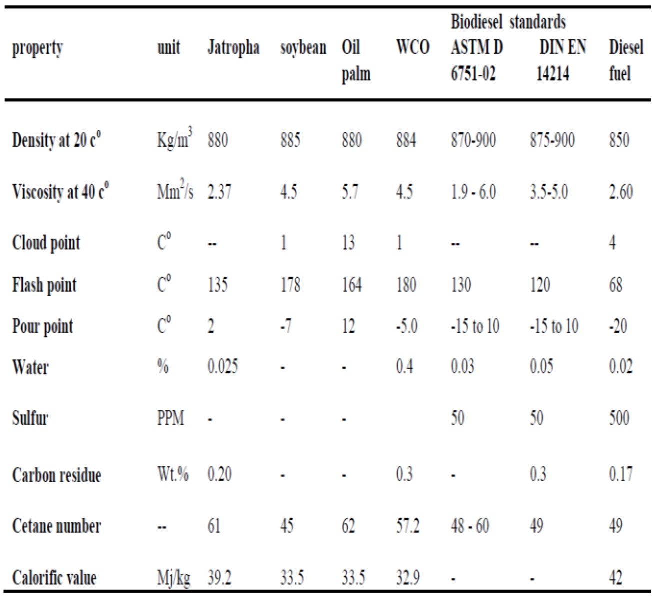
### 3.2.5 Lubricity and cold flow

Biodiesel's have higher lubricity than the petroleum diesel which means that an engine run on biodiesel will be less prone to wear and will last longer. However, the major property of biodiesel, which hampers its use as a neat fuel (B100), is the cold flow property otherwise known as the low temperature flow property. Biodiesel's have been reported to have relatively high cloud and pour point.

The cloud point is the temperature at which is the fuel starts toform crystals, with further decrease in temperature these crystals increase in size and quantity until the fuel gels and does not move again.

The cloud point is of more importance because it indicates the onset of filterability problems of the fuel in the fuel filter equipment.

**Table4. Biodiesel properties**



| property | unit | Jatropha | soybean | Oil palm | WCO | Biodiesel standards<br>ASTM D 6751-02 | DIN EN 14214 | Diesel fuel |
|---|---|---|---|---|---|---|---|---|
| Density at 20 c° | Kg/m$^3$ | 880 | 885 | 880 | 884 | 870-900 | 875-900 | 850 |
| Viscosity at 40 c° | Mm$^2$/s | 2.37 | 4.5 | 5.7 | 4.5 | 1.9 - 6.0 | 3.5-5.0 | 2.60 |
| Cloud point | C° | -- | 1 | 13 | 1 | -- | -- | 4 |
| Flash point | C° | 135 | 178 | 164 | 180 | 130 | 120 | 68 |
| Pour point | C° | 2 | -7 | 12 | -5.0 | -15 to 10 | -15 to 10 | -20 |
| Water | % | 0.025 | - | - | 0.4 | 0.03 | 0.05 | 0.02 |
| Sulfur | PPM | - | - | - |  | 50 | 50 | 500 |
| Carbon residue | Wt.% | 0.20 | - | - | 0.3 | - | 0.3 | 0.17 |
| Cetane number | -- | 61 | 45 | 62 | 57.2 | 48 - 60 | 49 | 49 |
| Calorific value | Mj/kg | 39.2 | 33.5 | 33.5 | 32.9 | - | - | 42 |

### 3.2.6 Economic Analyses

The cost of biodiesel is a great hindrance to its widespread use as it is very high, almost twice that of petroleum diesel. This high cost is influenced bythe cost of raw materials, Cost of processing i.e. transesterification and purification, and market value of the by-products. Of all three mentioned above, the cost of the raw material holds the highest stake in the determination of the priceof biodiesel. The cost of raw materials amount to about 80% of the total operating cost, this is due to the high cost of the feedstock oils. This high cost of feedstock oils is in turn attributed to the unavailability of sufficient agricultural land for the cultivation of the oil seeds for biodiesel production as the food materials for food production. More so, some of these oil seeds like the oil palm are edible while others are also used in various aspects of the chemical industry like the soap industry, hence the demand for these oil seeds are high as against its supply.

The production and usage of biodiesel however will reduce a country's reliance on imports of crude oil, provide new labor and open a new market for the domestic crops in addition to its advantage of being more environmentally friendly and more sustainable than the conventional petroleum diesel. In other words, biodiesel creates a balance between a country's domestic agriculture, economic development and ecological stability. It therefore becomes important for all to support the cultivation of these non-edibleoil seeds, not to depend on only for food production but also for biodiesel production. The government should provide incentives and subsidies to farmers who grow these oil seeds and reduce the taxes levied on these crops. More so with the new regulations to de-aromatize the petroleum diesel which will increase the production cost of petroleum diesel and the increasingcrude oil prices, the price of petroleum diesel is foreseen to increase to a value that biodiesel can conveniently compete with it economically.

### 3.3 The Standards of biodiesel

Standards and quality control of manufacturing and distribution of biodiesel are being developed to assure that reliable and consistent fuels are supplied to users. As an alternative fuel, biodiesel has physical and chemical properties qualifying to the operation of diesel engines. These properties play a vital role in quality control in the petroleum-based diesel fuel industry.

### 3.4 Evaluation

To evaluate for materials that are more suitable for biodiesel production, there are three important points to consider:

- Availability of these materials.
- Properties closer to the standard diesel.
- Economic of the biodiesel In comparison with fossil diesel.

Also, in comparing edible and non-edible materials, that is; oil palm and soybean oil as edible oil with jatropha and waste cooking oil as non-edible oil, it could be seen from the result that non edible oils are more suitable to produce biodiesel because they are not competitive with the food material, this will preserve the food sources alone even though biodiesel from edible oils have properties closer to standard diesel properties. Also, biodiesel from edible oils are not economical Compared with non-edible oils. Jatropha and waste cooking oil are more readily available than oil palm and soybean oils. Jatropha appears to have several advantages as a renewable diesel feedstock, because it is non-edible and can be grown on marginal lands; it is potentially a sustainable material for biofuel production. The high oil content of Jatropha curcas indicates that Jatropha curcas is suitable as non-edible plant oil feedstock in oleo chemical industries. Jatropha has been planted in several arid regions, in these regions it only yields about 0.5 ton per hectare. The seeds contain about 30% oil. Biodiesel from Jatropha curcas so obtained were found to be comparable to those of fossil diesel conforming to the American and European standards.

**Table 5. Production cost versus material [11].**

| Material | Production cost (US$/ton) |
|---|---|
| palm oil | 543 |
| Soybean oil | 771 |
| Jatropha oil | 445 |
| Waste cooking oil | 224 |

Table 5 shows the cost of biodiesel production base on the materials used. It can be seen that amongst the four materials to be evaluated, waste cooking oil can be seen as the cheapest and most economical as source. The biodiesel properties of waste cooking oil also conforms to the American and European standards. Average international prices for virgin vegetable oils and yellow grease used as feedstock for biodiesel production in 2007 (US$/ton) [11].

## IV. CONCLUSION

Biodiesel is a good alternative fuel for diesel engines because it is environmentally friendly and renewable in nature. There are different methods of producing biodiesel but transesterification of vegetable oil and fats are predominantly used method these days. Researchers focus more on the production of biodiesel using edible oils but the use of non-edible oil for biodiesel production has contributed immensely to its cost reduction. *Jathropha curcas* oil and waste cooking oil which isnon-edible oils are very cheap and economical materials in the production of biodiesel. The governments should make full use of these biodiesel resources and ensure international diesel security as a long lasting supplement.

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