

# Production of Biodiesel from Soybean Seeds

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**Abstract:** In order to control carbon dioxide emissions from transportation system, introduction of biofuels has been proposed and used for both gasoline and diesel (methyl ester from vegetable oils). This research aimed at producing biodiesel from oil extracted from Soybean seeds. The soybean seeds were sun-dried for two days and grind into fine particles with grinding machine. The oil was extracted from grinded soybean seeds by solvent extraction methods. The extracted oil was transesterified to biodiesel using Sulphuric acid as a catalyst. The biodiesel was analyzed by Gas Chromatography Mass Spectroscopic (GC-MS). Physicochemical properties of biodiesel were determined using predictive models based on fatty acid composition and American Society for Testing for Materials (ASTM) protocols. Data obtained were subjected to appropriate statistical analysis. The biodiesel extracted from the soy bean oil had seven fatty acids, namely Palmitic acid: 30.80%, Palmitoleic acid: 6.40%, Stearic acid: 17.60%, Oleic acid: 22.50%, Linoleic acid: 15.30%, Arachidic acid: 4.4% and Behenic acid: 3.0%. The highest carbon carbon chain  $C_{16} - C_{18}$  of 92.6% was recorded in Soy bean seed diesel while percentage composition of saturated, monounsaturated and polyunsaturated fatty acids in the biodiesel extracted from lipids are 55.80%, 28.90% and 15.30%. The results of physicochemical parameters are Specific gravity: 0.8720; kinematic viscosity: 2.31; flash point: 135; cloud point:-6; pour point:-4; volatile matter: 99.10; refractive index: 1.42; heat of combustion: 36.88; density: 0.8720; Ash content:0.02; Acid value: 0.35; saponification value: 225; Peroxide: 2.9; iodine values:45.33; free fatty acids:1.19; cetane number:72; Oxidative stability :6.85; long chain saturated factor: 26.55 Cold filter plugging point:68.99; degree of unsaturation :65.31; higher heating :43.22 water content: 0.02. Soybean is a promising candidate and alternative source for the production of diesel fuel. The produced biodiesel conform with the acceptable global standard

**Keywords:** Bio-diesel, Soybean seeds, Renewable alternative fuel, Trans-esterification process.

## 1. INTRODUCTION

Population growth, Urbanization expansion, technological advancement and improve living standards are the factors behind geometrical increase in energy demand [1]. Though it is non-renewable and has greater impact on global climate, petroleum fossil fuels are the dominant and leading source of energy throughout the world [2]. About 36% of the world's energy comes from petroleum fossil oil and 22% from gas [3]. This dependency on fossil fuel has also led to rise in pollution and hike in its price.

According to British Petroleum Energy Outlook to 2035 [2], there is projection of 34% increase in world energy consumption between 2014 and 2035, and conventional fossil fuel remain the most dominant energy source (accounting for almost 80%) powering and dictating the global economy in 2035 (down from 86% in 2014). When total energy consumption and greenhouse gas (GHG) emissions are considered (after the industry and the building sectors), the transport sector that are heavily depends on oil-derived liquid products such as gasoline and diesel, globally occupies the third place. This consumption level is predicted to increase by 60% by 2030 [4].

Rapid increase in both global energy demand and emissions of poisonous gasses associated with the use of fossil fuels has driven the search for alternative, renewable and lower environmental impact energy sources [5, 6]. Thus, it has become apparent that biofuel is destined to make a substantial contribution to the future energy demands of domestic and industrial economies [6]. Vegetables oils are one of the significant renewable feedstock that can provides secure, abundant cost effective and clean source of energy for developing nations like Nigeria

Nigeria will be free from her over-dependence on crude oil reserves through adoption as well as increase in the use of biodiesel [7]. Besides, conventional fossil fuel has been reported as being finite. While it is worthy to note that biodiesel will not completely displace petroleum diesel, biodiesel has its place as an alternative fuel and can be a source of lubricity as an additive to diesel fuel. The emissions produced from biodiesel are cleaner compared to petroleum-based diesel fuel. Particulate emissions, soot, and carbon monoxide are lower since biodiesel is an oxygenated fuel.

Biodiesel is produced from vegetable oil or animal fat reacts in the presence of a catalyst (usually a base) with an alcohol (usually methanol) to give the corresponding alkyl esters (for methanol, fatty acid methyl esters) [8]. Biodiesel is non-toxic, biodegradable

and a portable fuel produced from renewable sources [9, 10] and it is one of the technically and economically feasible options to tackle the fast depletion of fossil fuels and environmental pollution [1]. The other benefit of biodiesel fuel is that it can be used in any mixture with petro diesel fuel, as it has very similar characteristics [9].

Also, among the crops grown in the tropics, considerable work has been reported using vegetable oils such as soybean oil, palm oil, palm kernel oil, sunflower oil, rape seed oil, *Jatropha* oil, etc. [7] for biodiesel production. One of the most promising alternatives fuel is the vegetable oils and their derivatives. The first use of vegetable oil in a compression ignition engine was first demonstrated through Rudolph Diesel who used peanut oil in his diesel engine. The use of oils from coconut, soy bean, sunflower, safflower, peanut, linseed, rape seed and palm oil amongst others have been attempted. Common vegetable oil in the country include palm oil, palm kernel oil (PKO), groundnut oil, cottonseed and soybean.

Considerable works have been reported across the globe on biodiesel production from vegetable oils but few studies were found for vegetable oils common in Nigeria. As at year 2000, limited studies were reported in the literature on production and testing of biodiesel from Nigerian Lauric oils. Recent development only shows some improvement on the exploitation of Nigeria vegetable oils as resources for biodiesel production; such include transesterification of palm kernel oil, transesterification of groundnut oil. With increasing attention on the use of these oils for biodiesel production, there is a need to further research on biodiesel production from Vegetables oils and their sources. This will serve as awakening calls and measures to draw attention of government towards shifting from petroleum fossil diesel to safer and environmental friendly biodiesel from vegetable oils and their sources.

Reported biodiesel production from Vegetables oil are mainly from processed Vegetables oils like soy bean oil, groundnut oil, palm oil and palm kernel oil while there is little or no reported diesel production directly from their seeds (groundnut seeds, soy bean seeds, palm kernel seeds). Production of diesel directly from processed vegetables oils may not give clear picture of quality and quantity of diesel produced because of various production processes involved which may likely to affects the final quality of diesel produced. Hence, there is need for shift from processed vegetables oils to their sources since processed vegetables oils are meant for various industrial and other applications. Therefore, this study is focused on the characterization and production of biodiesel from soy bean seeds. The objectives of this study includes oil extraction from soya-bean seeds, Trans-esterification of soya-bean oil to Fatty Acid Methyl Ester and Physicochemical properties of the methyl esters produced from soya-bean oil.

## 2. MATERIALS AND METHODS

### 2.1 Sample collection

The Soya bean seeds were purchased from Ilesha, Osun state, Nigeria. The area lies within the latitude and longitude of 7°37'40.40"N and 4°44'29.80"E respectively. The soybean seeds were sun-dried for two days and grinded into fine particles with grinding machine.

### 2.2 Extraction of oil from Soybean seeds

This was carried out by Bligh and Dyer method [11] modified by Nascimento *et al.* [12]. A mixture of methanol and chloroform (2:1) was made and added to 1g of powdered soya bean seeds. The mixture was kept for 24 h at room temperature to dissolve the oils properly. It was centrifuged at 3000 rpm for 10 min and supernatant was collected. The process was repeated by adding 2 mL of chloroform to the pellet and shaken properly. It was again centrifuged at 3000 rpm for 5min and supernatant was separated. After adding 2 mL of 1% potassium chloride (KCL) to the supernatant, two separate layers were formed. The upper layer (methanol/powdered soy bean seeds) was decanted and the lower chloroform layer containing the extracted lipids was collected in another test tube. The upper layer (methanol/powdered soy bean seeds) was extracted again using the same procedure but with 1 mL of 1% potassium chloride (KCL). The bottom phase (chloroform/lipids) were combined and evaporated for 24 h in a drying oven at 80°C.

### 2.3 Trans-esterification of Soybean oil to Fatty Methyl Ester (FAME)

This was achieved using the Lepage and Roy [13] method, with slight modifications by Anitha and Sriraman [14]. The crude oils (about 10 mg) was dissolved using 2 mL of a freshly prepared mixture of chloroform-methanol (2:1, v/v) in a 10 mL Pyrex tube with a Teflon-sealed screw cap. 1 mL of methanol as reagent and 0.3 mL of sulfuric acid 95-97 % (Scharlau Chemie, reagent grade) as catalyst were added, for the trans-esterification of about 10 mg of lipids. After screwing the lid, the tube with the mixture was weighed and vigorously shaken for 5 min. Finally, the tube was incubated at 100 °C for 10 min and cooled to room

temperature. Followed by addition of 1 mL of distilled water for phase separation (by adding water two distinct phases are formed, the upper layer rich in water, methanol, glycerol, and sulphuric acid, and the lower layer rich in chloroform and esters). Then, 1 mL of distilled water was added for a gentle water washing of esters with chloroform layer (more dense than the water layer) followed by discard of the water rich upper layer (less dense). This step was repeated twice more. The esters rich layer was filtered using a disposable Nylon syringe filter (0.2  $\mu\text{m}$  pore, 13 mm diameter, Cronus, UK). The chloroform was then evaporated to dryness from the esters in a laboratorial hood, at room temperature (of about 25 °C).

## 2.4 Gas Chromatography and Mass spectroscopic of Soybean seeds Fatty Acid Methyl Ester

This was done according to the method described by Medina *et al.* [15] using a Shimadzu 2010 gas chromatography (Shimadzu Scientific Instruments, Columbia, MD, USA) equipped with a flame Ionization detector and a diethylene glycol succinate capillary column (30m  $\times$  0.25  $\times$  0.25  $\mu\text{m}$ ). Both initial column temperature and injection port temperature were 180°C. Detector temperature was 230°C, and this was increased to 300°C at a temperature gradient of 15°C/min. Biodiesel sample (100  $\mu\text{L}$ ) was placed in capped test-tubes, saponified with 1 ml of saturated KOH-CH<sub>3</sub>OH solution at 75°C for 10min, and then subjected to methanolysis [16] with 5% HCL in methanol at 75°C for another 10 min. Thereafter, the phase containing the fatty acid methyl esters was separated by adding 2 mL of distilled water, and methanol was recovered. The components were identified by comparing their retention times and fragmentation patterns with those of the standards. Six fatty acid methyl esters (C16:1, C17:0, C18:1, C18:2 and C18:3) were used as the standard materials.

## 2.5 Physicochemical Characterization of the Coconut Methyl Esters Produced

### 2.5.1 Specific Gravity

A 3ml aliquot of the methyl ester was weighed and its density calculated using the equation below

$$\text{Density (\%)} = \frac{\text{Mass of Methyl ester(g)}}{\text{Volume of water(ml)}} \times 100$$

Then, the specific gravity of the methyl ester was calculated using the formula in equation below

$$\text{Specific gravity (\%)} = \frac{\text{Density of Methyl Ester (g)}}{\text{Density of water(g)}} \times 100$$

### 2.5.2 Relative density

This was carried out using the method described by ASTM D6751 [17]. The mass was obtained by weighing the empty and filled (Soy bean seeds methyl ester) Erlenmeyer flask. The difference was the mass of the Soybean seeds methyl ester. With these two values, the density was obtained, which is mass divided by volume.

### 2.5.3 Moisture content

This was determined by method described by AOCS. Cd 3-25 [18] An empty flask was weighed with and without the amount of methyl ester and dried in an oven at 105°C for 7h, weighing each 2 hours till a constant weight was obtained, and finally the weight was taken and compared with the initial recorded weight. The percentage moisture content was calculated using below following equation.

$$\text{Moisture content (\%)} = \frac{(W_1 - W_2) \text{ (g)}}{W_2 \text{ (g)}} \times 100$$

Where,

$W_1$  = Original weight of the sample before drying

$W_2$  = Weight of the sample after drying

### 2.5.4 Viscosity

This was done using the method of AOAC [19]. The methyl ester was gradually poured into the viscometer until its lobe was almost filled and then it was placed in a water bath and allowed to heat up to an equilibrium temperature of 40°C. The methyl ester on the broad arm was sucked through the narrow arm until it reached the upper mark above the lower lobe of this narrow arm. The methyl ester was then allowed to flow back to the lower mark just below the lower lobe. The time taken for the flow (flow time, t) was recorded. Then, the viscosity was calculated using below equation:

$$\text{Viscosity (\%)} = \frac{v p_1 t_1}{p_2 t_2} \times 100$$

Where,

n = Viscosity of the methyl ester mm<sup>2</sup>/s

v = Viscosity of water mm<sup>2</sup>/s

p<sub>1</sub> = Density of the methyl ester, Kg/m<sup>3</sup>

p<sub>2</sub> = Density of water, Kg/m<sup>3</sup>

t<sub>1</sub> = Time taken for the soybean methyl ester to flow back

t<sub>2</sub> = Time taken for the water to flow back

### 2.5.5 Flash Point

The flash point was determined according to open cup method described by ASTM D6751, [17]. The cup was filled with a sample of the methyl ester up to the mark (75ml) and the cup was heated with a bunsen burner maintaining a small open flame from an external supply of natural gas. Periodically, the flame was passed over the surface of the methyl ester. When the flash temperature was reached the surface of the methyl ester caught fire. The temperature (at the moment) was noted and recorded as the flash point temperature.

### 2.5.6 Cloud Point

This was carried out based on the ASTM D6751, [17] method. A test tube with a thermometer inserted in it, was filled with a sample of the methyl ester. The methyl ester was cooled at 2°C/min rate and continuously monitored until a white cloud appeared on the bulb of thermometer. The temperature that corresponds to the first formation of a cloud in the methyl ester was recorded.

### 2.5.7 Pour Point

This was carried out using method described by ASTM 7-96a [20]. A sample of the methyl ester in a capillary tube was solidified; thereafter, it was attached to a thermometer and inserted into a gradually heating beaker of water. The temperature at which the sample started moving in the capillary tube was recorded as pour point.

### 2.5.8 Percentage ash content

The ASTM D874, [21] method was used for the determination of percentage ash content. To a washed porcelain crucible, One gram of coconut methyl ester was added. It was weighed after drying and cooling in an oven at 100°C and a dessiccator respectively. Then, heated for 4 hours at 600°C inside a muffle furnace, after which it was removed and subsequently cooled in a dessiccator and weighed again. The percentage ash content was calculated using below equation:

$$\text{Ash content (\%)} = \frac{A-B}{C} \times 100$$

Where,

A = Weight of crucible + ash,

B = Weight of crucible

C = Weight of original sample

### 2.5.9 Refractive Index

This was determined according to the method of Alamu *et al.* [22] using a refractometer (Abbe refractometer bench). The power switch was turned on; the illuminating lamp came up and the display showed 0000. A drop of the methyl ester was introduced on the working surface of the lower refracting prism. The rotating arm and the collecting lens cone of the light gathering illuminating units were rotated so as to make the light-intake surface of the upper light-intake prism to be illuminated evenly. The field of view was observed through the eye piece and the adjustable hand wheel was rotated so as to make the line dividing the dark and light areas fall in the cross line. The dispersion correction hand wheel was rotated so as to get a good contrast between the light and dark area and minimum dispersion. The read button was pressed and the refractive index was displayed on the screen

#### 2.5.10 Conductivity

This was determined using a conductivity meter. The conductivity meter was standardized with 0.01M KCl solution. The electrode was rinsed with deionized water, wiped and dipped into a sample of the ethyl ester and left for some time to stabilize the reading. The reading was displayed on the screen and then recorded in micro Siemens per centimeter ( $\mu\text{S}/\text{cm}$ ).

#### 2.5.11 Heat of Combustion

This was carried out using a bomb calorimeter by method of AOAC [19]. The calorimeter was standardized using benzoic acid. To a crucible of the calorimeter, a weighed amount of the methyl ester (1.058g) was added and the fuse wire was attached between the electrodes. Thereafter, it was placed in the bomb, which was pressurized to 18atm of oxygen. The bomb was placed in a vessel containing a measured quantity of water (2000g). The ignition circuit was connected and the water temperature was noted. After ignition, the temperature rise was monitored every minute till a constant temperature was reached and recorded. The pressure was released, the length of unburned fuse wire was measured and the residue titrated with 0.7M of sodium carbonate solution using phenolphthalein as indicator. The heat of combustion was calculated using below equation:

$$\text{Heat of Combustion} = \frac{E\Delta T - 2.3V}{g(\text{KJ/Kg})} \times 100$$

Where,

E = Energy equivalent of the calorimeter using benzoic acid

$\Delta T$  = Temperature rise

L = Length of burnt wire

V = Titration volume

g = Weight of sample

#### 2.5.12 Acid Value

This was determined by method of ASTM D6751 [17]. A standard alcoholic KOH solution (0.5M) was prepared by dissolving KOH (pellet) with ethanol. The solution was then filtered and stored in brown bottle for Five days. Furthermore, a mixture of 95% ethanol and diethyl ether in a ratio of 1:1 (v/v) was prepared. 5 grams of the methyl ester was dissolved in 25ml of 1:1 (v/v) mixture of ethanol and diethyl ether. The solution was titrated with 0.5M ethanolic KOH solution in the presence of 5 drops of phenolphthalein as indicator until the end point (colourless to pink) was recognized. The total acidity (acid number) in KOH/g was calculated using below equation.

$$\text{Acid value} = \frac{V \times N \times 56.1}{M}$$

Where,

V= Volume expressed in milliliter of 0.5M solution of ethanolic KOH,

M= Weight of the sample in gram

N= Concentration of ethanolic KOH

### 2.5.13 Peroxide Value

The method of AOAC [19] was used for the determination of peroxide value. To a 30 ml of mixture of glacial acetic acid and chloroform (3:2, v/v), 2.206g of the methyl ester was dissolved in the mixture, then, 20% of potassium iodide (0.5 ml) was added and the solution swirled in the dark for one minute after which 75ml of distilled water was added. The mixture was titrated with 0.1M sodium thiosulphate with vigorous shaking until the yellow colour of the iodine had disappeared. Starch indicator (0.5ml) was added then to obtain a blue colour and titration continued until all the blue colour had disappeared. The peroxide value was calculated using below equation:

$$\text{Peroxide Value} = \frac{(S-B) \times M \times 100}{\text{Sample weight(g)}}$$

Where,

S = Sample titre value in ml

B = Blank titre in m

M = Molarity of Sodium thiosulphate

### 2.5.14 Iodine Value

This was determined using the method of AOAC [19]. An aliquot of the methyl ester (0.8825g) was weighed into a conical flask, tetrachloromethane (15ml) and 25 ml of Wig's solution was added. This mixture was placed in a stoppered conical flask, swirled gently and placed in a dark cupboard for one hour after which 20 ml of 20% potassium iodide solution and 100ml of distilled water were added. After gentle shaking, liberated iodine was titrated with 0.1M sodium thiosulphate solution until the yellow colour of the iodine had appeared. Starch indicator (1ml) was added then to obtain a blue colour and titration continued until all the blue colour had disappeared. The iodine value was calculated using below equation

$$\text{Iodine Value} = \frac{(B-S) \times M \times 100}{\text{Sample weight(g)}}$$

Where,

S = Sample titre value in ml

B = Blank titre in ml

M = Molarity of Sodium thiosulphate

### 2.5.15 Percentage Free Fatty Acid

This was carried out using the method of AOAC [19]. Two grams of the methyl ester was weighed into a conical flask and 10 ml of 95% ethanol was added. This was then titrated with 0.1 M sodium hydroxide using phenolphthalein as an indicator. The conical flask was shaken constantly until a pink colour that persisted for 30 seconds was obtained. The percentage free fatty acid was obtained from the equation below

$$\text{Free Fatty Acid} = \frac{V \times M \times 2.92}{\text{Sample weight(g)}} \times 100$$

Where,

V= Volume of 0.1M Sodium hydroxide used in ml

M= Molarity of NaOH.

#### 2.5.16 Determination of other Properties Based on Fatty Acid Methyl Esther (FAME) Profiles

This was achieved using predictive models of Fatty Acid composition. Saponification value (SV), iodine value (IV), Cetane number (CN) degree of unsaturation (DU), long chain saturated factor (LCSF) and cold filter plugging point (CFPP) was determined by equations proposed by Islam *et al.* [23]:

$$SV = \sum (560 \times A_i) / M_{wi}$$

$$IV = \sum (254 \times A_i \times D) / M_{wi}$$

$$CN = 46.3 + (5458/SV) - (0.225 \times IV)$$

$$DU = \sum MUFA + (2 \times PUFA)$$

$$LCSF = 0.1 \times (C16:0, \text{ wt\%}) + 0.5 \times (C18:0, \text{ wt \%}) + 1 \times (C20:0, \text{ wt \%}) + 1.5 \times (C22:0, \text{ wt\%}) + 2.0 \times (C24:0, \text{ wt\%})$$

$$CFPP = (3.1417 \times LCSF) - 16.477$$

Where, D is the number of double bonds,  $M_w$  is the fatty acid (FA) molecular mass, and  $A_i$  is the percentage of each fatty acid (FA) component of the microalgae oil.

The kinematic viscosity ( $\nu$ ), density ( $\rho$ ) and higher heating value (HHV) of each Fatty Acid Methyl Ester (FAME) were determined by equation proposed by Ramirez-Verduzco *et al.* [24]:

$$\ln(\nu_i) = -12.503 + 2.496 + \ln(M_i) - 0.178 \times N$$

$$\rho = 0.8463 + 4.9/M_i + 0.0118 \times N$$

$$HHV_i = 46.19 - 1794/M_i - 0.21 \times N$$

Where,

( $\nu_i$  is the kinematic viscosity of at 40 °C in mm<sup>2</sup>/s;  $\rho_i$  is the density at 20 °C in g/cm<sup>3</sup>; HHV<sub>i</sub> is the higher heating value in MJ/kg of *i*th FAME, N is the number of double bonds,  $M_i$  is the molecular mass of each fatty acid component.

Predictive oxidative stability was calculated based on C18:2 and C18:3 content of Fatty Acid composition as suggested by Park *et al.* [25]:

$$OS = 117.9295 / (\text{wt\% } C_{18,2} + \text{wt\% } C_{18,3} + 2.5905) \quad (0 < 100)$$

Where,

wt%  $C_{18,2}$  is the content of linoleic, wt%  $C_{18,3}$  is the content linolenic acids (wt%) ( $0 < X < 100$ ); and OS is the oxidation stability in hours.

### 3. RESULTS AND DISCUSSION

#### 3.1 Gas Chromatography and Mass spectroscopy analysis

The composition, quality and quantity of fatty acids in biodiesel of soybean seeds were examined through gas Chromatography and Mass spectroscopy analysis (Figure 1). The biodiesel extracted from the soy bean oil had seven fatty acids, namely Palmitic acid:



30.80%, Palmitoleic acid: 6.40%, Stearic acid: 17.60%, Oleic acid: 22.50%, Linoleic acid: 15.30%, Arachidic acid: 4.4% and Behenic acid: 3.0% Table 1. The highest carbon carbon chain  $C_{16} - C_{18}$  of 92.6% was recorded in Soy bean seed diesel while percentage composition of saturated, monounsaturated and polyunsaturated fatty acids in the biodiesel extracted from lipids were 55.80%, 28.90% and 15.30% respectively (Table 1).

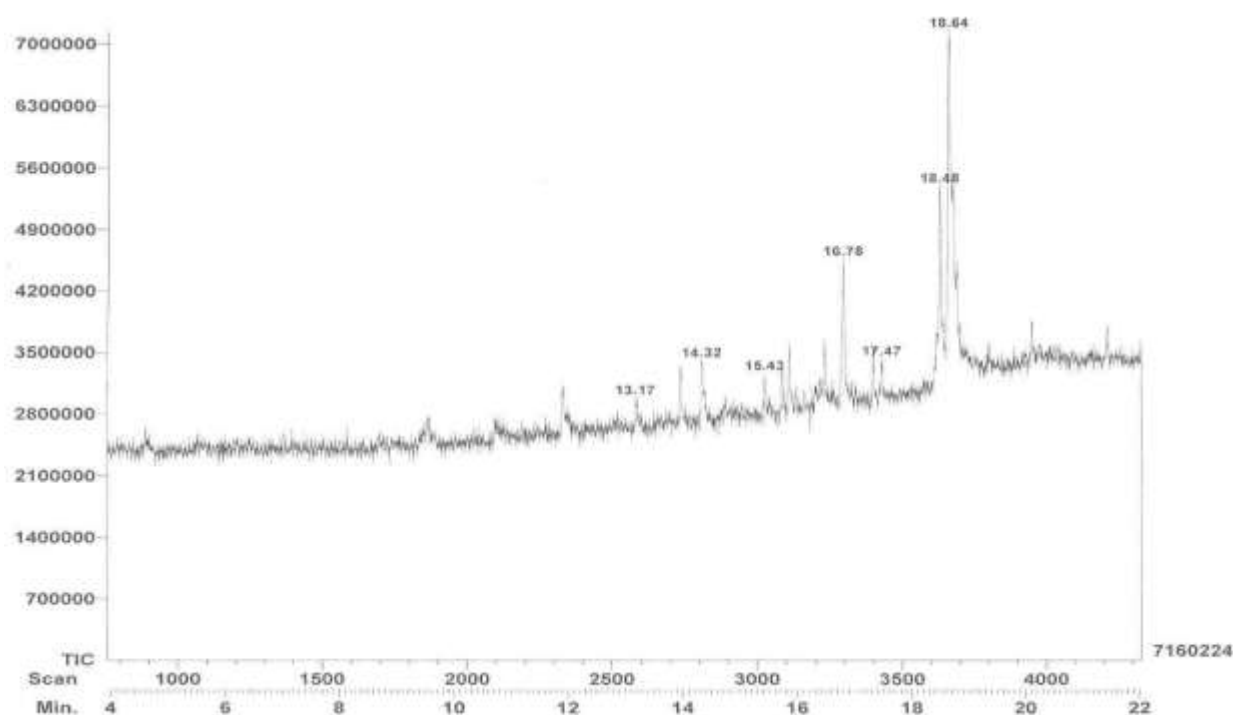


Figure 1: Chromatogram of diesel obtained from soy bean seeds

Table 1: Gas chromatography and mass spectroscopy of soybean seed Fatty Acid Methyl Ester showing fatty acids composition in percentage of total fatty acid methyl esters components

Structure	Fatty Acids	Molecular Formula	Soy bean seed diesel
Percentage Composition of each Fatty Acids			
$C_{16:0}$	Palmitic Acid	$C_{16}H_{32}O_2$	30.80



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$C_{16:1}$	Palmitoleic Acid	$C_{16}H_{30}O_2$	6.40
$C_{18:0}$	Stearic Acid	$C_{18}H_{36}O_2$	17.60
$C_{18:1}$	Oleic Acid	$C_{18}H_{34}O_2$	22.50
$C_{18:2}$	Linoleic Acid	$C_{18}H_{32}O_2$	15.30
$C_{18:3}$	Linolenic Acid	$C_{18}H_{30}O_2$	-
$C_{20:0}$	Arachidic Acid	$C_{20}H_{40}O_2$	4.4
$C_{20:1}$	Gondoic Acid	$C_{20}H_{38}O_2$	-
$C_{22:0}$	Behenic Acid	$C_{22}H_{44}O_2$	3.0

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$C_{16} - C_{18} (%)$	92.6
Saturated Fatty Acid (%)	55.80
Monounsaturated Fatty Acid (%)	28.9
Polyunsaturated Fatty Acid (%)	15.30

### 3.2 Physicochemical properties of Biodiesel obtained from Soybean seeds

#### *Specific Gravity*

The specific gravity of the Soya bean biodiesel is 0.8720 (Table 2). The specific gravity obtained in the current work conform satisfactorily with stipulated standard by US (ASTM D6751-08) AND EUROPE (EN14214) (Table 2). Biodiesel is lighter than the oil which will promote atomization and confer lower viscosity.

#### *Kinematic Viscosity*

Kinematic viscosity is a measure of a fluid's resistance to flow. The greater the viscosity, the less easily the liquid will flow. The viscosity of biodiesel is very important since it affects the operation of fuel injection equipment particularly at low temperatures when the increase in viscosity affects the fluidity of the fuel or leakage at high temperature when too thin [26]. The value recorded for kinematic viscosity in this study is 2.31 (Table 2).

#### *Flash Point*

The flash point is the lowest temperature to a barometric pressure of 101.3kPa at which liquid sample provides sufficient vapour for the air-vapour mixture above the surface to flash momentarily on exposure to standard source of ignition. It is a measure of flammability of fuels therefore making it an important safety criterion in transportation and storage. The flash point of Soy bean (135) biodiesel obtained in the above study is within the US (ASTM D6751- 08) 130 min and EN 14214 120min biodiesel standard (Table 2).

#### *Cloud Point*

The cold flow temperatures of biodiesel are very important quality criteria as fuel that is frozen can cause blockage of the fuel lines and filters and then starve the engine of fuel. The two most essential criteria are the cloud and pour points. The cloud point is the temperature at which the amount of wax in the fuel is sufficient to gel it, thus making it the lowest temperature at which the fuel can flow [26]. In this study, the values obtained for cloud point (-6) conform satisfactorily with US (ASTM D6751- 08) standard range of -3 - +12 (Table 2).

#### ***Pour Point and Cold Flow Filtration***

The pour point is the temperature at which the fuel would not pour even when the containing vessel is tilted. The pour point of (-4) of biodiesel satisfied required standard range (Table 2). The cold flow characteristics of biodiesel depends on chain length and degree of unsaturation, with long chain saturated fatty acid esters displaying particularly unfavorable cold temperature behavior.

#### ***Volatile matter***

The volatile matter for the soybean biodiesel in this work is 99.10 (Table 2).

#### ***Refractive Index***

The values of refractive index obtained for soybean biodiesel is (1.42) and it conform satisfactorily with required biodiesel standard (US (ASTM D6751- 08) (Table 2).

#### ***Lower Heating Value (Heat of combustion)***

This is the amount of heat released when a given weight of the fuel is burnt. The standard value for heat of combustion as stipulated by US (ASTM D6751- 08) and EN 14214 is min 35, the value (36.88) recorded for soybean diesel in this study met the set standard (Table 2) but less than that of petroleum diesel (47 KJ/kg). This is responsible for the lower torque output and higher specific fuel consumption of biodiesel [27].

#### ***Density***

The density of soybean biodiesel is 0.8720 and it fall within the standard range (0.86 – 0.90g/cm<sup>3</sup>) (Table 2).

#### ***Ash content***

The biodiesel of soybean is within the standard value (US (ASTM D6751- 08) of 0.02 set for Ash content (Table 2).

#### ***Acid Value***

The acid value (0.3 mgKOH/g) of the soy bean biodiesel in this study is within the ASTM D6751- 08 and EN 14214 standard value of 0.5 for biodiesel (Table 2).

#### ***Saponification Value***

Saponification value represents the number of milligrams of potassium hydroxide required to saponify 1g of fat. It is a measure of the average molecular weight (or chain length) of all the fatty acids present. Saponification value is used in checking adulteration [27]. Soya bean biodiesel have saponification values of 225 mgKOH/g r thereby indicating the presence of high fatty acids in the biodiesel. These values are high for vegetable oils hence Soybean is widely used for soap production as it lather very well and confer hardness to soaps. Soap inhibits the separation of biodiesel and glycerin fraction [28] and should be reduced if reasonable biodiesel yield is to be achieved. High amount of soap can result in irregular combustion and thick exhaust smoke but would also increase the cleanliness of the fuel internal components and reduce friction between rubbing parts.

#### ***Peroxide values***

Biodiesel can oxidize during storage and handling and in the presence of heat and air, leading to the formation of peroxides, acids, gums and deposits. The peroxide value of soybean biodiesel in the present study is 2.9 (Table 2). These values are important from the point of view of fuel stability in storage.

### ***Iodine Value***

The iodine value is the amount of unsaturation in fatty acids. The unsaturation is in the form of double bonds which reacts with iodine compounds. The higher the iodine number, the more C=C bonds are present in the fat. The biodiesel from soybean diesel in this work had iodine values (mgI<sub>2</sub>/g) of 45.33 (Table 2) and is within the ASTM D6751- 08 and EN 14214 standard value of 120 (maximum). This is an indication of the presence of small number of C=C bonds in the diesel as a result of the high degree of saturation. The in flexure point for good fuel quality is 100 hence the biodiesel would be suitable for use as alternative fuel for diesel engines as far as carbon deposit formation is concerned. It would also have high oxidative resistance and semisolid at room temperature.

### ***Free Fatty Acids***

The result recorded for free fatty acids (%) in soybean diesel is 1.19 (Table 2).

### ***Cetane number***

Cetane Number (CN) is a measure of the ignition quality of diesel and biodiesel fuels. The value of cetane number in biodiesel from soybean diesel is 72 (Table 2) and fall within the ASTM D6751- 08 and EN 14214 biodiesel standard. For diesel engine usage, it is an important factor, as it affects cold startability, indelibility, engine noise, engine vibrations and incompleteness of combustion that can increase harmful exhaust emissions [29].

### ***Oxidation index***

High level of saturation will have high oxidative and thermal stability due to the presence of fewer vacant chains, leading to a slower deterioration rate of the lipid characteristics [30]. Once oxidative instability is initiated, it increases according to the peroxidation chain mechanism [31]. Oxidation can be caused by several factors that includes, water content, presence of heat and oxygen, leading to the breakdown of unsaturated fatty acids and the formation of primary oxidation products such as hydroperoxides and conjugated dienes [32]. Oxidative stability (hr) of 6.85 observed in biodiesel obtained from soybean diesel conforms satisfactorily within ASTM D6751- 08 and EN 14214 biodiesel standard (Table 2).

### ***Long Chain Saturated Factor (LCSF)***

The biodiesel obtained from oil extracted from soybean had 26.55 (Table 2) of long chain saturated factor (LCSF)

### ***Cold Filter Plugging Point***

For Saturated fatty acids, the molecules harden at higher temperature and are solid at room temperature. As the biodiesel cools down, solid crystal are formed which can plug fuel filters hence the name cold flow plugging point. This temperature is called the cold flow plugging point. The plugging point for biodiesel in this study is 68.99°C (Table 2) which is higher than the ambient temperature.

### ***Degree of Unsaturation***

In this study, degree of unsaturation of soybean biodiesel is 65.31 (Table 2)

### ***Higher heating value***

The higher heating value recorded in this work for soybean biodiesel is 43.22 (Table 2)

### ***Water content***

Water content for soybean biodiesel is 0.02 (Table 2).

**Table 2:** Physico-chemical properties of the Soybean seeds biodiesel in comparison with US (ASTM) D6751-08 and Europe (EN 14214) standard

S/N	Physicochemical parameters	Soy	bean	USA (ASTM)	EUROPE
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		<i>Seeds</i>	D6751-08	(EN 14214)
<b>1</b>	Specific Gravity	0.8720	0.88	
<b>2</b>	Kinematic Viscosity (mm <sup>2</sup> /s) at 40 <sup>0</sup> c	2.31	1.9-6.0	3.5-5.0
<b>3</b>	Flash Point (°C)	135	130min	120min
<b>4</b>	Cloud Point (°C)	-6	-3+12	-
<b>5</b>	Pour Point (°C)	-4	- 15 - +10	-
<b>6</b>	Volatile Matter (%)	99.10		
<b>7</b>	Refractive Index	1.42	1.479	
<b>8</b>	Heat of Combustion (MS/kg)	36.88	35min	35min
<b>9</b>	Conductivity (MS/cm)			
<b>10</b>	Density (g/cm <sup>3</sup> )	0.87	0.86-0.90	
<b>11</b>	Ash Content (%)	0.02	0.01	0.02
<b>12</b>	Acid Value (mgKOH/g)	0.39	0.5	0.5
<b>13</b>	Saponification Value (mgKOH/g)	225		
<b>14</b>	Peroxide Value (meq/kg)	2.9		
<b>15</b>	Iodine Value (mgI <sub>2</sub> /g)	45.33		120max
<b>16</b>	Free Fatty Acid (%)	1.19		
<b>17</b>	Cetane Number	72	47min	51min
<b>18</b>	Oxidative Stability (hr)	6.85		3.0min
<b>19</b>	Long Chain Saturated Factor (LCSF) <sup>0</sup> C	26.55		
<b>20</b>	Cold-Filter Plugging Point (CFPP)	68.99		
<b>21</b>	Moisture Content (%)			
<b>22</b>	Degree of Unsaturation	63.51		
<b>23</b>	High Heating Value (HHV)	43.22		
<b>24</b>	Water Content	0.02	500ppm	500max
<b>25</b>	Calorific Value (Kcal/kg)			

#### 4. CONCLUSION

The methods and other production processes involved in the above work reveal the diesel of high quality. The solvent extraction employed in oil production was perfect and effective for soybean seeds while huge success was recorded during trans esterification of the extracted oil to biodiesel. All parameters examined during characterization of soybean biodiesel were in conformity to required International standard. Soy bean biodiesel may be a resource to obtain biodiesel. So, soybean seeds are good starting materials for biodiesel production. Biodiesel characteristics such as viscosity, pour point are comparable to that of diesel thereby making it feasible as a means of alternative fuel for diesel engines

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