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Research Article

Assessing the Combination of Jatropha Curcas Linnaeus and Cassia Fistula Oil Extracts as Bio-Fuel Source at Various Percentages

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Abstract. This project analysed the oil extract from two inedible seeds; Jatropha curcas Linnaeus and Cassia Fistula as a requirement for biofuel source. The quest for a clean source of energy has risen in recent times and this project attempts to proffer a solution to this challenge, whereby energy can be produced without the creation of an imbalance in the ecosystem. The purpose of this project is to examine the potentials of Jatropha curcas Linnaeus and Cassia Fistula for bioenergy production in Nigeria and reduce the reliance on fossil fuel. We compared the oils from both inedible seeds through series of test like UV-Vis spectrometer, viscosity, peroxide, saponification and acid value tests. From the analysis performed, it was observed that the combination of the two oils will be viable for biofuel production. The combination of the two oils at ratio 9:1 yielded a kinematic viscosity of 291.1nms^{-2} and a dynamic viscosity of 249.18. While the individual kinematic and dynamic viscosities of Jatropha curcas Linnaeus was 190.01 nms^{-2} and 160.56 respectively. It was also observed that the peroxide value of the mixture was 4.0mMol/kg and the saponification value was 160.2mgKOH^{-1}.

Keywords. Jatropha curcas Linnaeus; Cassia fistula; Biofuel source; Soxhlet extraction; Chemical tests

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1. Introduction

Energy is a very vital part of living; it is needed for virtually everything in life, most specially transportation, heat and electricity, hence the need for abundance of this energy for use by man. Presently, the demand for energy is more than the supply making deployment of renewable energy necessary such as solar, wind, biomass etc. to meet the increasing energy demand [1].

Bioenergy (biomass) encompasses a wide variety of renewable energy technologies that use plant matter, plant residues, or plant-derived process wastes as fuel. These biomass resources can be used directly as solid fuels to produce heat, or they can be converted into other energy carriers such as liquid and gaseous fuels and electricity.

The demand for conventional fuel has been increasing yearly and the only way to improve our biofuel yield is to be able to meet up with the ever-growing demand for high yield, high quality biofuel fuel with petroleum-based fuel. Jatropha curcas Linnaeus and Cassia Fistula has been selected as the raw material for the production of biofuel (pure plant oil) and because of its in-edible nature it does not compete with edible seeds. Cassia Fistula oil still has a low percentage oil property to produce biofuel (pure plant oil).

This research focuses on the analysis of non-edible feed stock (Jatropha curcas Linnaeus and Cassia Fistula). This material is used to test the level of produce and to enhance the use of non-edible feedstock over edible feedstock to avoid competition with food material. The tests been carried out on the Jatropha curcas Linnaeus and Cassia Fistula oil extracts range from UV-Vis tests, viscosity, density, dynamic viscosity tests, acid value, saponification, peroxide value tests. Jatropha curcas Linnaeus and Cassia Fistula are of great importance to the society as it is medicinal.

1.1 Biomass

Biomass is organic matter derived from living, or recently living organisms. Biomass can be used as a source of energy and it most often refers to plants-based materials that are not used for food or feed, and they are precisely called lignocellulose biomass. As energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel [2].

1.2 Biofuel

Biofuel is one of the alternatives that can be used instead of fossil fuel and these form of fuel is gotten from biomass, these can be used to power diesel engines, generators, heavy duty machineries, etc. Liquid biofuel are made up of three different forms; Biodiesel, Pure Plant Oil, and Bioethanol.

1.3 Inedible Seeds for Biofuel Production

In discussing the use of oil seeds for biofuel, it involves the use of oil seeds for Biodiesel or as Pure Plant Oil. There are two types of oils; edible and non-edible oils. It has been discovered that biodiesel from edible oils have properties closer to standard diesel properties for example edible oil-producing plants such as the African palm, groundnuts, cotton seeds, sunflower, canola [3]. Due to higher prices of edible vegetable oils compared to diesel fuel, waste vegetable oils and non-edible crude vegetable oils such as Jatropha curcas Linnaeus, neem, Cassia Fistula are now being used as biodiesel sources. There are disadvantages of using edible oil such as: higher viscosity, lower volatility, the reactivity of unsaturated hydrocarbon chains. Due to these disadvantages, vegetable oil is not used directly as biodiesel, until its characteristics are enhanced.

Non-edible oils are more suitable to produce biodiesel because they are not competing with food material sources, this will preserve the food sources which are also very important to the society.

Jatropha curcas Linnaeus seed has shown a promising prospect towards the production of biofuel (biodiesel) from its oil. The oil is non-edible making it a good source for biofuel production that should not affect cost of edible oil.

2. Methodology

The pods of Cassia fistula were harvested by hand from its surrounding trees in Covenant University, Ota. They were air dried for a period of 3 weeks, the pods were torn open with the use of a table knife and the seeds expelled from their husk by hand. Jatropha curcas seeds were obtained from Jos, towards the northern part of Nigeria.

2.1 Soxhlet Extraction of Oil from Jatropha curcas Seed and Cassia Fistula

The extraction process can be classified based on the nature of the material (solid, liquid, gas, supercritical fluid). For solid to liquid, this extraction is useful for the isolation and purification of naturally occurring sources while liquid to liquid is a more common method depending on solubility properties of components.

There are numerous solvents being used for extraction such as organic solvents and inorganic solvents. Organic solvents are less dense than water while inorganic solvents are denser than water. Commonly used organic solvents are diethyl ether, toluene, hexane, ethyl acetate, ethanol, and inorganic solvents are dichloromethane, chloroform and carbon tetrachloride.

Most of the oil content of Jatropha is in the seed of the plant having about 40% of oil and cassia seed plant having about 10%. During the experiment hexane was used as the solvent for the oil extraction with the Soxhlet apparatus.

The Soxhlet apparatus reuses the hexane in the round bottom flask and hexane has an extraction grade of 48-98% with a narrow distillation range. The extraction was carried out in a Soxhlet apparatus, treating the raw material with hexane and recovering the oil by distillation of the resulting solution of oil and hexane in the Soxhlet apparatus called miscella. Evaporation and condensation from the distillation of miscella recovers the hexane absorbed in the material. The hexane thus recovered is reused for extraction. The boiling point of hexane is (67°C/152°F) and it evaporates on reaching this temperature leaving the oil and little hexane.

Figure 1. Soxhlet extraction in progress

The Jatropha and Cassia Fistula seeds were ground to increase the surface area that is to come in contact with the hexane solvent. The ground seeds was placed in a filter paper which was then weighed on a digital weighing scale. The weighed ground Jatropha seed was well packaged and placed into a chamber or thimble in Soxhlet extractor with hexane poured into the round bottom flask with heat applied via the heating mantle. This was allowed to react for about two hours and then the liquid mixture was removed from the Soxhlet extractor and the solvent distilled out of the mixture (oil extract). The seed cake left in the thimble contained some solvent that can be reused.

2.2 The Mixture of Jatropha and Cassia Oil

The six samples of 5 ml each, which was analysed:

(i) Sample JP — pure extract from Jatropha seed (5 ml).
(ii) Sample CF — pure extract from Cassia seed (5 ml).
(iii) Sample A — 2 ml Cassia + 3 ml Jatropha (Ratio 40%: 60%).
(iv) Sample B — 1.5 ml Cassia + 3.5 ml Jatropha (Ratio 30%: 70%).
(v) Sample C — 1 ml Cassia + 4 ml Jatropha (Ratio 20%: 80%).
(vi) Sample D — 0.5 ml Cassia + 4.5 ml Jatropha (Ratio 10%: 90%)

2.3 Physical Test on oils

2.3.1 Ultraviolet Spectroscopy Analysis of Jatropha and Cassia oil

The oxidation level of Jatropha curcas Linnaeus and Cassia Fistula oils can be determined using ultraviolet spectroscopy. The Jatropha and Cassia Fistula's oil quality can be examined based on the absorption band range of 200-300nm. To carry out this experiment a blank reading with n-Hexane was used as a neutral solvent. The six samples were diluted with hexane and the readings taken.

2.3.2 Viscosity Test

Viscosity of a fluid is a measure of its resistance to gradual deformation by shear stress or tensile stress. Viscosity is a property of the fluid which opposes the relative motion between the two surfaces of the fluid in a fluid that are moving at different velocities. A viscometer is an instrument used to measure the viscosity of a fluid. Viscometers only measure under one flow condition. A standard volume of 20-22 ml Jatropha curcas Linnaeus extract was used, while gradually increasing the volume of Cassia Fistula extract been added from 1.0 ml to 5.0 ml to give 6 samples readings. The samples were left for some time to observe the changes in the colour and viscosity.

2.4 Chemical Tests on oils

2.4.1 Free Fatty Acid Test

The free fatty acids are estimated by titrating it against potassium hydroxide (KOH) using phenolphthalein as indicator. The acid value, is mg KOH required to neutralize the free fatty acids present in 1g of sample. It is expressed as oleic acid (octadic-9-enoic acid) equivalent [4].

$$\text{Calculation: Acid value mg/KOH/g} = \frac{\text{Titre value} \times 0.1\text{M KOH } \times 56.10}{\text{Weight of sample (g)}}.$$

2.4.2 Saponification Value

Saponification value is the amount (mg) of alkali required to neutralize a definite quantity (1g) of an oil. This value is useful for comparative study of the fatty acid chain length in oil. A known quantity of oil is refluxed with and excess amount of alcoholic KOH. After Saponification, the remaining KOH is estimated by titrating it against a standard acid.

$$\text{Calculation: Saponification value} = \frac{(\text{B} - \text{S}) \times 0.5 \times 56.10}{\text{Weight of sample (g)}} = \frac{(\text{B} - \text{S}) \times 28.05}{\text{Weight of sample (g)}}.$$

Where B is the molarity of HCL is the molarity of KOH; 56.1 is the Molecular Mass of KOH the blank titre value; S is the sample titre value; 0.5.

2.4.3 Peroxide Value

Rancidity is brought about by action of air (oxidative) or by microorganisms in the oil. In oxidation rancidity, oxygen is taken by the oil with the formation of peroxides. Peroxide value is the measure of the peroxides contained in the oil. The peroxides present are determined by titration against thiosulphate in the presence of KI using starch as indicator [5].

$$\text{Calculation: Periodic value} = \frac{(\text{Vs} - \text{Vb}) \times \text{Molarity of titrant} \times 10^3 \text{gkd}^{-1}}{\text{W}}.$$

Where Vb is the Titre for blank; Vs is the Titre for sample; W is the weight of sample in grams.

3. Results and Discussion

Very few experiments have been conducted with the combination of two oils for biofuel. This experiment assessed Jatropha curcas Linnaeus and Cassia Fistula oil extracts as biofuel source at various percentages. Determining the physical properties; UV-Vis spectrometer test, viscosity test, density test; of both feedstock, as well observing their chemical properties; acid value, peroxide value and saponification value. From the tests conducted, various tables emerged.

3.1 UV/Vis Spectrometer Test

Ultraviolet spectroscopy is a technique used to quantify the light that is absorbed and scattered by a sample (a quantity known as the extinction, which is defined as the sum of absorbed and scattered light). The ultraviolent spectrum result shows the level of oxidation and Absorption as the ultraviolent light passes through. During the test a "blank" was taken, using n-Hexane. The oil samples were mixed with the hexane because of its high concentration, with a ratio of 0.1 ml to 4.4 ml of each sample to n-hexane. The high degree of UV absorbance reveals that the oil has undergone oxidation (in the graphs below).

From the UV/Vis test conducted the tables below were obtained for the different samples.

Table 1. Absorption wavelength 206 nm-212 nm

Samples	Absorption
Sample JP	2.271
Sample CF	2.764
SampleLE A	2.136
Sample B	2.887
SampleE C	2.952
Sample D	2.533

Table 2. Absorption wavelength 266nm

Samples	Absorption
Sample JP	0.417
Sample CF	0.791
Sample A	0.405
Sample B	0.888
Sample C	0.936
Sample D	0.505

The presence of peaks represents the existence of conjugated diene and triene systems. The principle of the analytical procedure is that the oxidation of oils leads to the formation of conjugated double bonds.

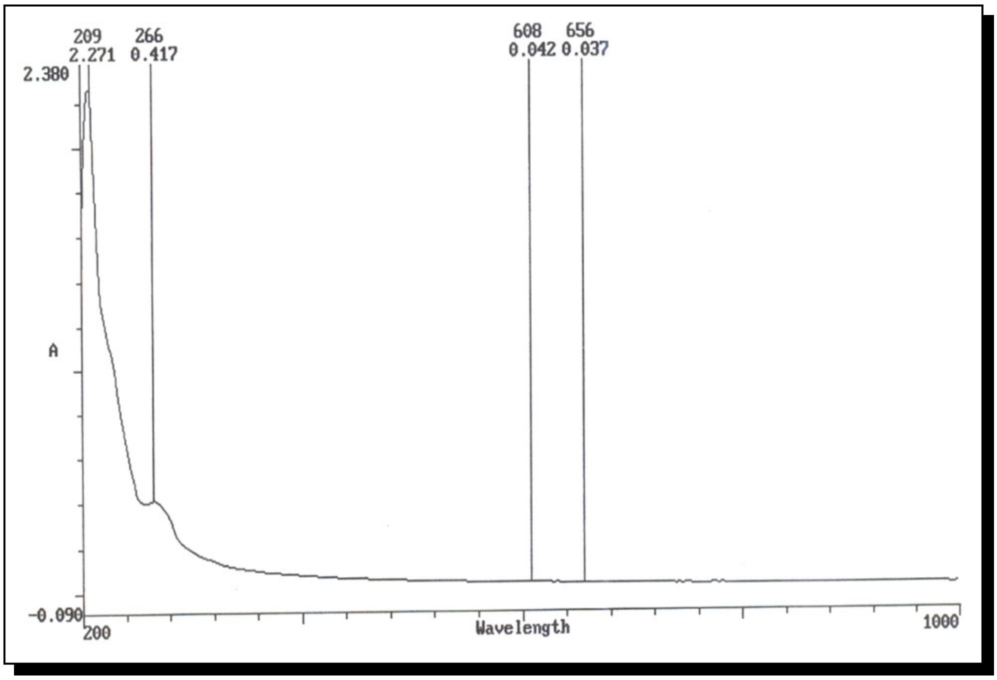

Figure 2. Sample JP (100% Jatropha oil)

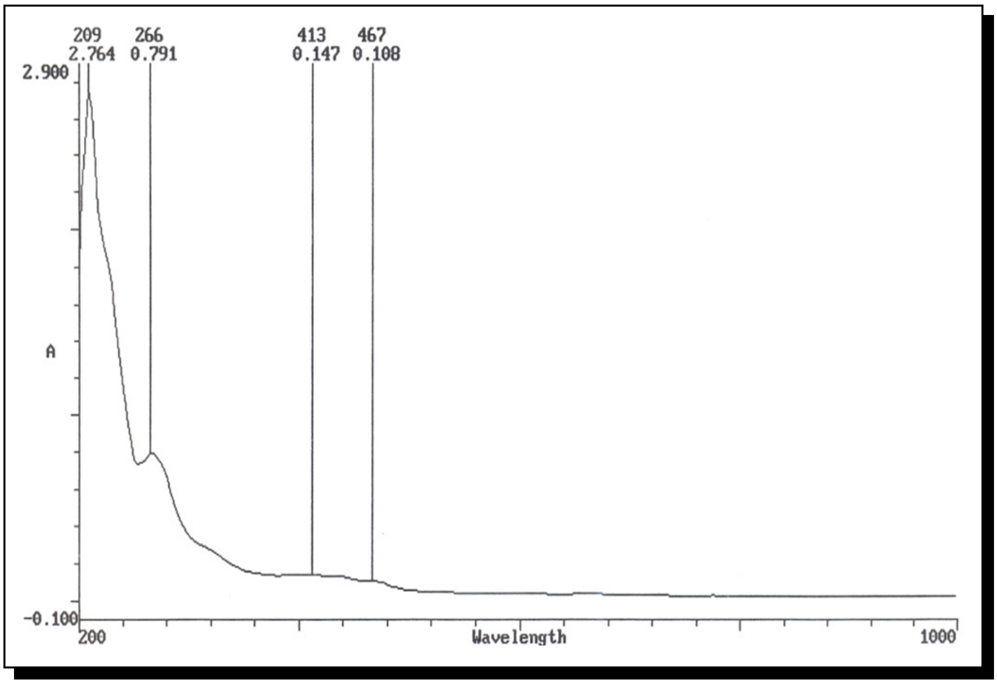

Figure 3. Sample CF (100% Cassia fistula oil)

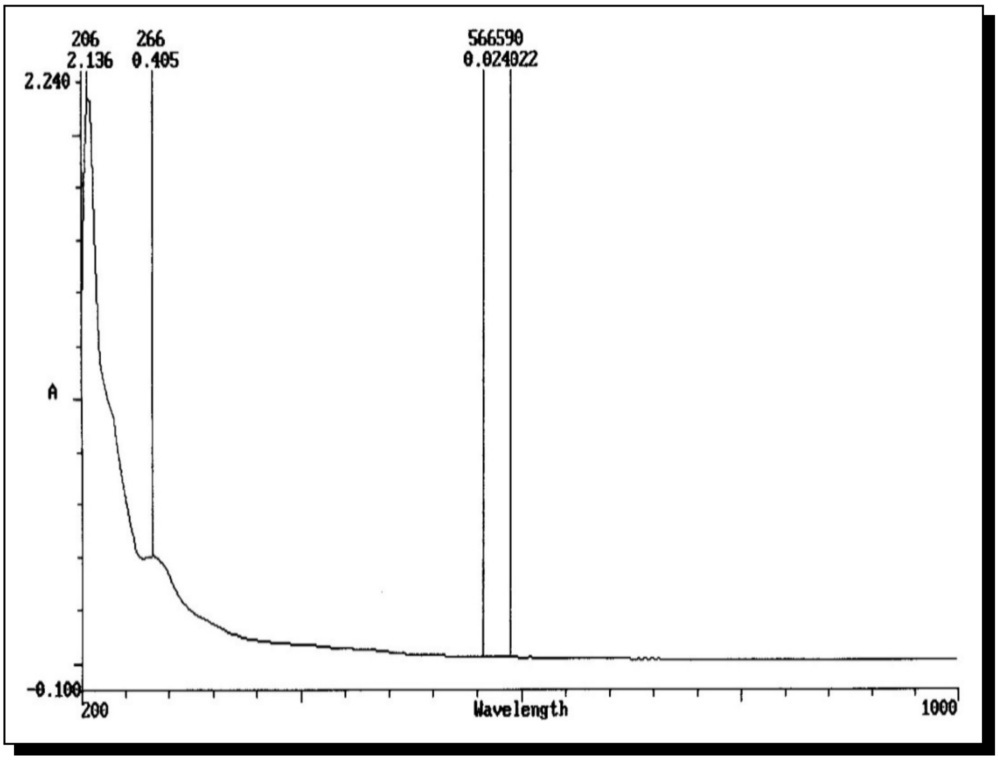

Figure 4. Sample A (Ratio 40%: 60% of CF: JF oil)

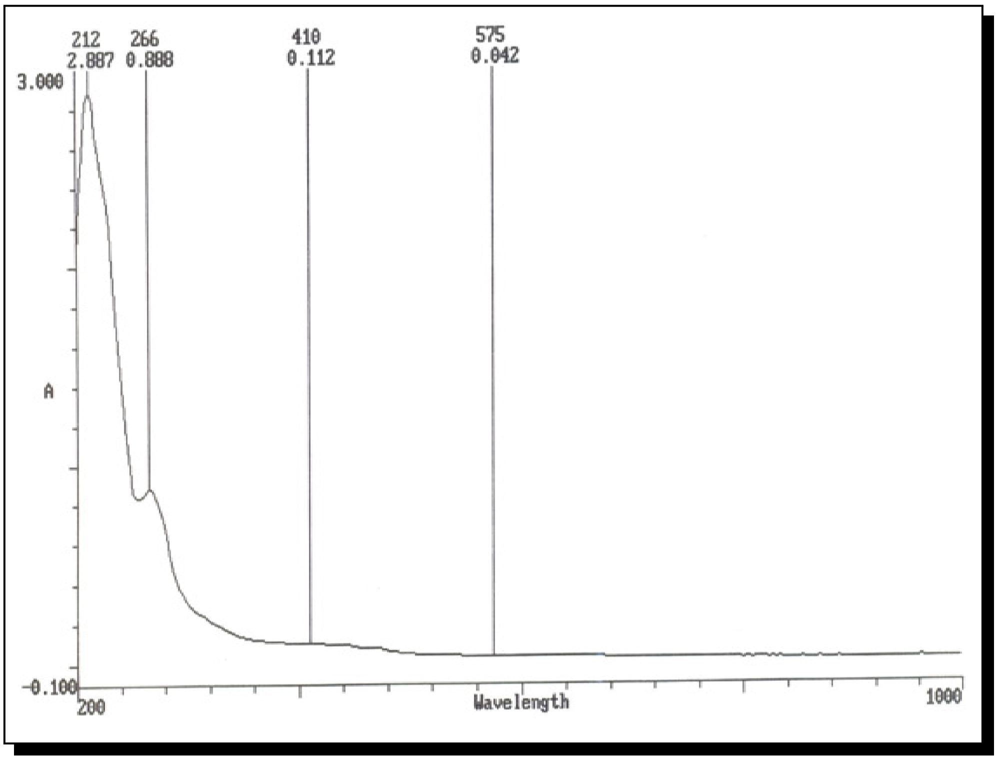

Figure 5. Sample B (Ratio 30%: 70% of CF: JF oil)

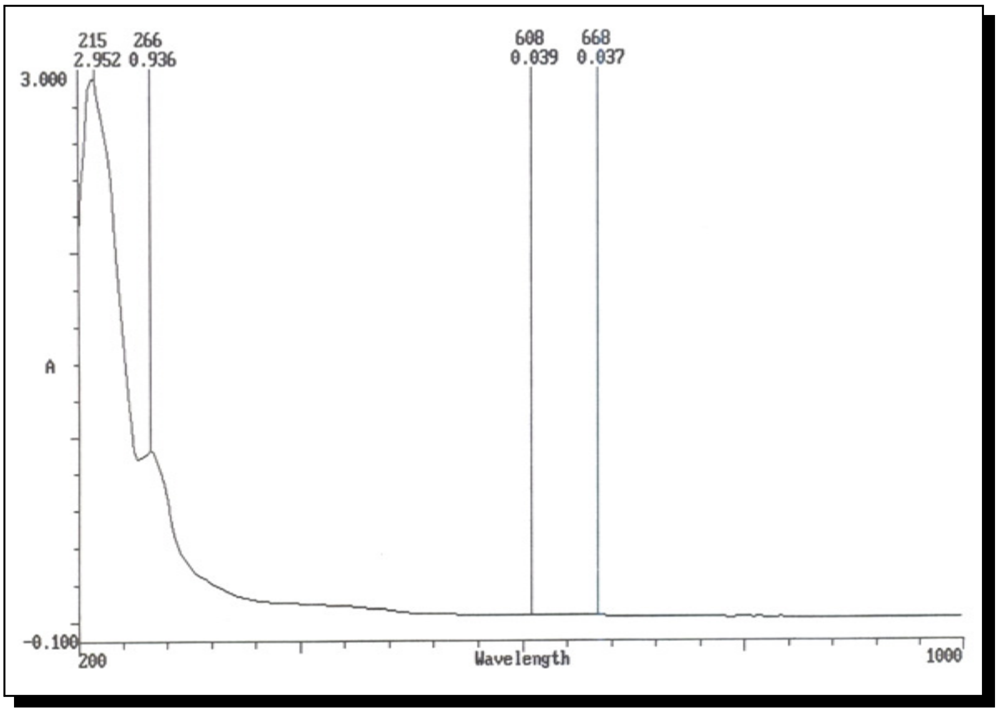

Figure 6. Sample C (Ratio 20%: 80% of CF: JF oil)

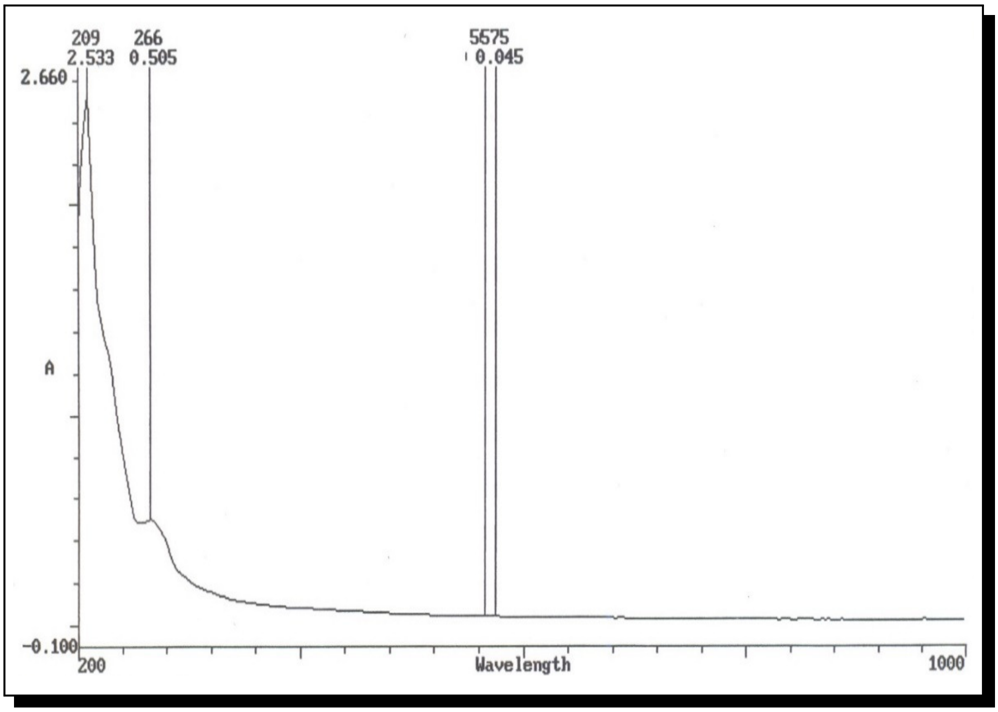

Figure 7. Sample D (Ratio 10%: 90% of CF: JF oil)

3.2 Viscosity and Density

Table 3 shows the combination of both oils (Jatropha and Cassia) and its resulting viscosity, density and mass. The viscosity of liquid fuels is their property to resist the relative movement tendency of their composing layers due to intermolecular attraction forces. Viscosity is generally an important parameter for diesel fuel. Fuel which is too highly viscous can cause damage in the fuel pump due to higher pressure. Too low viscosity may lead to lack of lubrication. It also influences the fuel during injection.

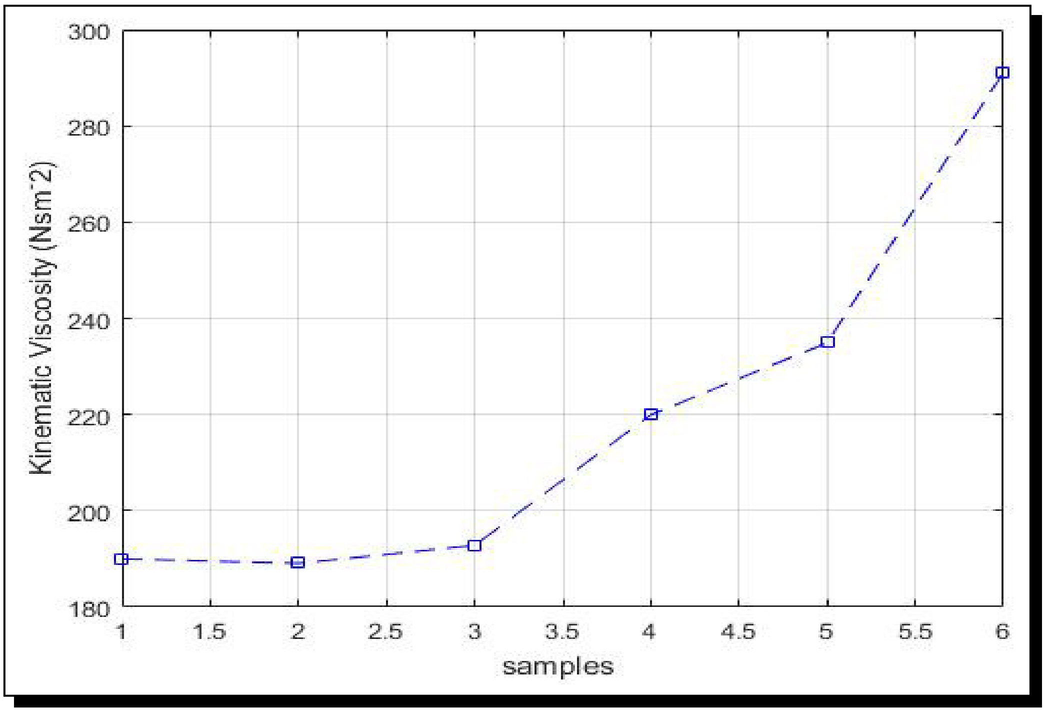

Figure 8. Graph of Kinematic viscosity

Table 3. Viscosity and Density results

S/N	Jatropha (ml)	Cassia (ml)	Viscosity (Nsm^{-2})	Mass (g)	Total Vol. (ml)	Density (g/cm^3)
1	20	0	190.008	16.9	20	0.8450
2	20	1.0	189.072	17.8	21	0.8476
3	20	2.0	192.816	18.7	22	0.8500
4	20	3.0	219.936	19.6	23	0.8522
5	20	4.0	234.936	20.5	24	0.8542
6	20	5.0	291.096	21.4	25	0.8560

Density is an important biofuel parameter, with impact on fuel quality. Fuel density directly affects the quality of atomization and combustion. Contamination of the biodiesel significantly affects its density; therefore density can also be an indicator of contamination.

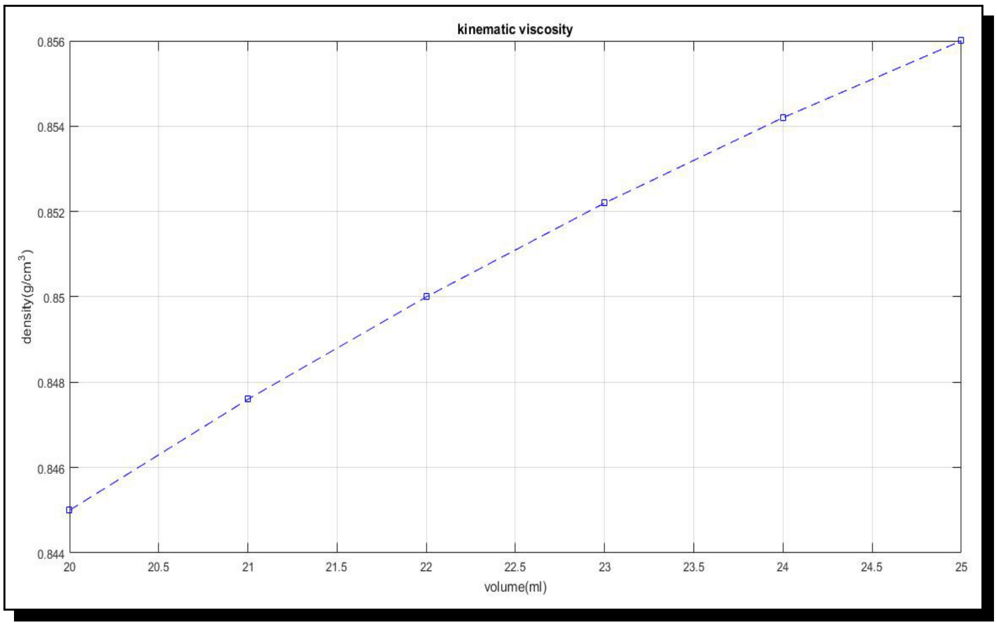

Figure 9. Graph of density

3.3 Chemical Tests

Table 4. Presentation of Chemical test results

Properties	Units	Jatropha	Cassia	Jatropha + Cassia (20 ml + 5 ml)
Acid value	KOH g-1	4.133	5.209	4.675
Peroxide value	mMol/kg	5.0416	8.500	4.000
Saponification value	Mg/g	246.2	258.6	160.2

Acid value indicates the amount of free fatty acids found in oil. More acid value implies more amount of free fatty acids, the presence of which interferes with methanol in transesterification process and in Table 4, it shows that Cassia Fistula has a higher acid value. This means that it may not give a good result if it undergoes transesterification into biodiesel. On the other hand, the combination of both oils gave an average value.

Peroxide value is the measure of peroxides contained in the oil. A high peroxide value facilitates high rancidity. From the table, it shoes that Cassia Fistula has a high peroxide value. This means that when the oil is extracted, it cannot be stored for a long period of time as it will give off a bad smell and will lose its requirements as oil for biofuel. The combination of both oils gave rise to a low peroxide value of 4.0 mMol/kg. This implies that it can be stored for a long period of time.

Cassia Fistula had the highest Saponification value. It is useful for a comparative study of the fatty acid chain length in the oil and also shows the propensity for soap making. In other words, Cassia Fistula oil extract will be viable for soap making than biofuel production.

The combination of both oils resulted into a low saponification value of 160.2 Mg/g. It will be viable for biofuel production.

In a nutshell, Cassia Fistula has a low oil yield as compared to Jatropha curcas Linnaeus. Pure Jatropha oil extract and the combination of Jatropha and Cassia Fistula oil extracts will be suitable for biofuel production, having an average acid value, low Peroxide value and low Saponification value. While Cassia Fistula will be suitable for soap making on having a high saponification value.

Oil quality is important when preparing oil seeds for direct use as a fuel. More investigation is necessary to determine what oil quality can be attained reasonably in representative rural conditions. In general, it is necessary to ensure low contamination of the oil, low acid value, high oxidation stability and low contents of phosphorous, ash and water. Crude Jatropha oil is relatively viscous, for example; more than rapeseed. It is characteristically low in free fatty acids, which improves its storability, though it's high unsaturated oleic and linoleic acids make it prone to oxidation in storage. However, the presence of unsaturated fatty acids (high iodine value) allows it to remain fluid at lower temperatures. Jatropha oil also has a high cetane (ignition quality) rating. The low Sulphur content indicates less harmful Sulphur dioxide (SO_2) exhaust emissions when the oil is used as a fuel. These properties make the oil very suitable for biofuel.

4. Conclusion

The search and use of alternative fuels has been an issue since the crude oil reserves were realized to be diminishing and as a consequence, increasing crude oil price. Early research on liquid fuels focused on vegetable oils but there are several problems on engine performance that made use of the vegetable oil itself. Also, one of the policies of the Biofuel Law in mandating the use of alternative fuels was to ensure the "availability of alternative and renewable clean energy without any detrimental effect to the natural ecosystem, biodiversity and food reserves in the country". Assessing the combination of Jatropha curcas Linnaeus and Cassia Fistula oil extracts as a bio-fuel source at various percentages helped us identify a new feedstock for biodiesel production.

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Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

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