Characterization of Oil and Biodiesel Produced from *Thevetia peruviana* (Yellow Oleander) Seeds

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Abstract: Background: There is increasing emphasis on renewable energy following recurrent economic crises and environmental concerns associated with the use of fossil fuels such as petrodiesel. Research into biodiesel production from oil-bearing renewable biomass sources can provide a more sustainable alternative to petrodiesel. This study evaluated the biodiesel yielding potential of *Thevetia peruviana* seeds. Methods: Oil was extracted from the seeds using Soxhlet and Cold-solvent extraction methods. Hexane-only (H-only) was used in the Soxhlet while Hexane/Ether (H/E) mixture and H-only were respectively used in the Cold extraction. The oil was processed using Methanol/Ethanol (M/E) mixture and Methanol-only (M-only) respectively to biodiesel via transesterification with sodium hydroxide as catalyst. The oil and biodiesel physicochemical parameters such as density, viscosity at 40^oC, Saponification value, Flash Point (FP) and Acid Value (AV) were determined using the American Standard for Testing and Material (ASTM D6751) methods. Results: The oil yields from Soxhlet, H/E and H-only extractions were: 62.3%, 51.9% and 45.8% respectively. The biodiesel yield in the M/E and M-only transesterifications were: 78.4% and 85.20% respectively. The density at 40^oC, viscosity, and saponification value of the oil were: $0.868g/cm^3$, $21.50mm^2/s$ and 120mgKOH/g respectively. The density at 40^oC, viscosity, FP and AV of the biodiesel were: $0.760g/cm^3$, $4.70mm^2/s$, 130^oC and 0.441mgKOH/g respectively. Conclusion: The seeds of *Thevetia peruviana* are viable sources for biodiesel production, and quality parameters of the biodiesel met the American Standard for Testing and Materials limits. However, further work to explore the optimization of the process and sustainability of the model is recommended.

Keywords: Biodiesel Production, *Thevetia peruviana*, Transesterification

1. Introduction

The World's energy demand is increasing geometrically as evidenced in the increasing demand for fuels for transportation, industrial as well as domestic activities. This sky-rocketing energy demand continues despite the attendant environmental pollution and global warming effect resulting from the use of petroleum-based fuels [1].

Within the last 20 years about 75% of human made CO_2 emissions were from burning of fossil fuels. Nigeria's oil, for example, has not guaranteed ecologically and socially acceptable development in the country. At present, there are over 11 oil companies operating 1,481 wells from 159 oil fields in the Niger Delta producing 2.7 million barrels of crude oil each day and flaring about 17 billion cubic metres of associated gas, spewing 2,700 tons of particulates, 160 tons of sulphur oxides, 5,400 tons of carbon monoxide, 12 and 3.5 million tons of methane and carbon dioxide, respectively in the process [2].

Modern biofuels have even been reported as a promising long term renewable energy source, which has the potential to address both environmental impacts and security concerns posed by current dependence on fossil fuels. In comparison to petroleum-based fuels, biodiesel offers reduced exhaust emissions, improved biodegradability, reduced toxicity and higher cetane rating which can improve performance and clean up emissions [3].

There is currently no commercial biodiesel plant that exists in Nigeria, except for a few production facilities that are notably not well documented. Production and consumption are still at their infancy stage. With the increasing emphasis on renewable energy following the global trend in the automobile industry, and biodiesel gaining increasing popularity, this is paving the way for increased consumer confidence in automobile engines' ability to utilize biodiesel of which Nigeria cannot be isolated. With an estimated

population of about 150 million people and a population growth rate of 2.38% (2007 estimate) and an average of 12 vehicles to 1000 people (1997 estimate), the potentials of biodiesel cannot be underestimated [4].

A variety of biolipids can be used to produce biodiesel. These include (a) virgin vegetable oil feedstock (rapeseed and soybean oils are most commonly used, though other crops such as mustard, palm oil, sunflower, hemp, and even algae show promise) (b) waste vegetable oil; (c) animal fats including tallow, lard, and yellow grease; and (d) non-edible oils such as algal oil, jatropha oil, neem oil, castor oil, and tall oil [5].

The use of edible vegetable oils from biomasses like those of soybean, sunflower, cotton seed, safflower, canola, palm fruits, fish oil and also animal fats for biodiesel production has recently been of great concern. This is because of the major criticism against large-scale fuel production from agricultural crops that it will consume vast expanse of farmlands and native habitat; compete with food materials and drive up food prices [6]. Hence, in view of these concerns and no reliable prospects for a massive compensatory scale-up in food production capacity (especially in developing countries like Nigeria), there is the need to intensify effort in exploring other potentially viable inedible oil-rich biomasses (such as algae, thevetia, jatropha, rice bran, neem, castor, etc.) for biodiesel production.

Thevetia peruviana is a plant that is grown as hedges and kept for its bright and attractive flowers, and has been grown in Nigeria for over fifty years basically as an ornamental plant in homes, schools and churches by missionaries and explorers. To date, despite the fact that there is high level of oil content in its kernel, about 60-65% [7] and valuable protein content in the seed, about 40-45% [8], it remains non-edible because of the presence of cardiac glycoside (toxins), hence the plant remains a plant of no significant economic value whereas it has a lot of potentials such as biofuel production.

Few works have been carried out using *Thevetia peruviana* seeds as feedstock for biodiesel production in Nigeria. Ibiyemi et al [8] studied the variation in oil composition between the different seed varieties of Yellow oleander while Olisakwe et al [9] carried out a comparative study of *Thevetia peruviana* and *Jatropha curcas* seed oils as feedstock for grease production amongst others. The present study was carried out to extract oil from *Thevetia peruviana* seeds using two methods (Soxhlet and Cold extraction), and process the oils to biodiesel via transesterification with methanol using sodium hydroxide as catalyst. The biodiesel produced from the seed oil was further characterized through ASTM standard tests for basic fuel properties such as density, viscosity, flash point and acid value.

2. Materials and Methods

Thevetia fruits were harvested from thevetia plantations grown as hedges in and around the University of Ibadan campus.

2.1. Feedstock Preparation

The harvested thevetia fruits were manually decorticated with stainless knife to reveal the kernels. Both thevetia and palm kernels were sundried under 5hours continuous sunlight to ease the removal of the seeds from them. After the seeds were removed from the kernels, they were milled using a hand-powered bench grinder. The milled seeds were subjected to 24hour continuous oven-drying period at 105°C until a constant weight was recorded.

Phosphorous, calcium, and magnesium are minor components typically associated with phospholipids and gums that may act as emulsifiers [10] or cause sediment, lowering yields during the transesterification process [11]. Hence, their percentage composition in the biomass was determined to establish if there would be a significant reduction in their composition upon taking the substrate through the solvent extraction process and the extracted oil through transesterification process.

The proportion of Total Phosphorus (%P), Sodium (%Na), Calcium (%Ca), and Sulphur (%S) in the milled biomasses were analyzed chemically according to the official methods of analysis described by the Association of Official Analytical Chemists [12]. The moisture content was determined using a Moisture analyzer equipment (АИД МХ-50 model) and the density of the milled biomasses was determined gravimetrically.

2.2. Oil Extraction

The milled oven-dried samples were used for the extraction process and two extraction methods were experimented *viz*: Soxhlet extraction and Cold solvent extraction (H/E mixture and H-only alcohol). For the Soxhlet extraction, 250g each of milled thevetia seeds were respectively placed in the thimble of a Soxhlet extractor with the use of about 800ml hexane for one extraction and a mixture of hexane and ether in ratio 1:1 v/v for another extraction. A round bottom flask containing the extraction solvent was fixed to the end of the extractor and a condenser was tightly fixed to the other ends of the extractor.

Once the sample for a particular extraction period was placed in the thimble of the extractor, the flask was heated at 60°C with the use of an electric mantle. As the solvent was heated in the boiler, the pure vapor rose through a by-pass and into the top part of the Soxhlet container (thimble) where the sample to extract was contained. In the condenser, the vapors condensed and drip into the sample-containing thimble. When the level of liquid reaches the same level as the top of the siphon, the liquid containing the extracted material was siphoned back into the boiler.

Each of the extraction processes carried out underwent a minimum of 40 cycles within the 8 hours period, which is considered necessary to complete an extraction [13]. After the extraction period the solvent was recovered at 65°C under vacuum using a rotary evaporator (Buchi Rotavapor: R-210 model), and the residual oils obtained thereafter were measured and recorded.

For the Cold Solvent extraction, the method used by Hossain et al [14] was adopted. 250g of the milled dried thevetia seeds were mixed with 600ml hexane and another 250g was mixed with 600ml H/E, 1:1, v/v mixture. The two separate sample/solvent mixtures were kept to settle in their respective labeled and well-sealed containers for 48 hours, with intermittent shaking (every 3-5hours) of the containers to enhance optimum percolation/breakage of the solvent into the cell wall of the ground seeds.

The 48hour period was followed by the separation of the sample/solvent mixtures by "squeeze-filtration" using two muslin cloths inserted into each other as a precaution to better reduce the amount of sediment that may probably be small enough to pass through the sieve pores into the solvent/oil mixture. The extracted oil/solvent mixtures were left to settle and air-dry for 24hours.

The clear oils were then decanted through a No 1 Whatman filter paper into labeled bottles, leaving behind the residual paste/sediments. Each of the decanted oils were individually evaporated under vacuum for about 5minutes at 60°C using the Buchi type Rotavapor (R-210 model). This was to ensure that all the extraction solvents in the oils are evaporated off. The residual oils obtained after evaporation was left to air-dry for about 2hours; the volume and weight of the oils were subsequently measured and recorded. The oils were kept for characterization and further processing via transesterification process.

The percentage of oils extracted from the milled samples by both the Soxhlet extraction and Cold extraction systems respectively was determined using equation below:

$$\% \text{ Oil content} = (W_o/W_u)\ 100\%$$

Where: W_o = weight of oil extracted (g)

W_u = weight of oven-dried biomass used for the extraction process (g)

2.3. Degumming of the Extracted Oil

This was accomplished by mixing 2% distilled water with the combined 482.2cm^3 thevetia oil obtained from the three different extraction processes; the mixture was agitated slightly. The water combined with the gums and precipitated out after allowing the mixture to settle for approximately one hour, and the water was drained off at the bottom of the oil. About three washings were carried out to remove a good quantity of any gum that might be present. The oil was heated on a heating mantle to a temperature above 100ºC, and allowed to cool to a temperature of 60ºC and then separated.

2.4. Characterization of the Extracted Oil

The physicochemical properties of the oil were determined following standard methods. Kinematic viscosity (KV) was determined using a calibrated Cannon-ubbelohde viscometer at a temperature of 40°C according to ASTM D445 (2006) [15]; density at 25°C was determined gravimetrically; Saponification value was determined by estimating the number of milligrams of KOH that neutralized the fatty acids resulting from the complete hydrolysis of 1g of oil; Fatty Acid Profile (FAP) was done according to the method described by Christie [16]; and Free Fatty Acid (FFA) was determined by selective formation of diethyl amide derivatives according to the method described by Kangani et al [17].

FFA (or fatty acids that have been unbound from the original triglyceride) occur in vegetable oils either because of contact with water or poor storage or because of the presence of enzymes that rapidly cleave the fatty acids from the glycerol backbone. When a homogeneous alkali catalyst is used, Gerpen [3] recommends that the maximum FFA content of the feed oil should be 5%. Otherwise, soaps will form, making separation of the glycerine difficult. Hence, an additional step to remove the FFA or to convert them via an esterification step would be necessary before using the feed oil in transesterification reaction.

2.5. Biodiesel Production by Transesterification Process

The process flow chart for a typical biodiesel production is presented in Figure 1. The transesterification reaction was carried out with Methanol-only (M-only) and Methanol/Ethanol (M/E) mixture (1:1, v/v) respectively in the presence of NaOH as catalyst. The molar ratio of alcohol to oil was 6:1 and 1% weight of the oil of NaOH catalyst was used at 65°C reaction temperature. Transesterification is a reversible reaction, thus the methanol quantity is required to shift the equilibrium favorably. The methanol to oil molar ratio, the weight percent of catalyst and the reaction temperature were chosen since they have been found to give optimal yields of methyl ester from seed oils [18].

An Erlenmeyer flask (500ml capacity) was charged with 250g of the thevetia oil and warmed to a desired temperature of about 55°C, which is less than the boiling point of methanol (65°C) in a water bath. While the oil was being warmed, a methanol quantity of 6:1 molar ratio methanol to oil and an optimal weight of NaOH pellets (1% weight of the oil) were mixed and heated in a separate flask to a desired temperature of 50°C on the magnetic stirrer until the NaOH pellets were completely dissolved.

After the complete dissolution of the NaOH pellets, the beaker was taken-off the magnetic stirrer, and the Erlenmeyer flask containing the warm oil was removed from the water bath and placed on the stirrer. The alcohol-NaOH mixture (i.e. sodium methoxide and/or sodium ethoxide) in the beaker was then added to the oil in the flask (including a corrode-resistant stir bar), the temperature of the hot plate was immediately increased to 65°C and the revolution of the stirrer was set at level four (i.e. 400rpm). The mouth of the flask was sealed with an aluminum foil to minimize alcohol evaporation during the conversion process. The reaction was allowed to continue for 1 hour, after which the stirrer was turned off, the stir bar was removed, and the content of the flask was immediately poured into a separatory funnel.
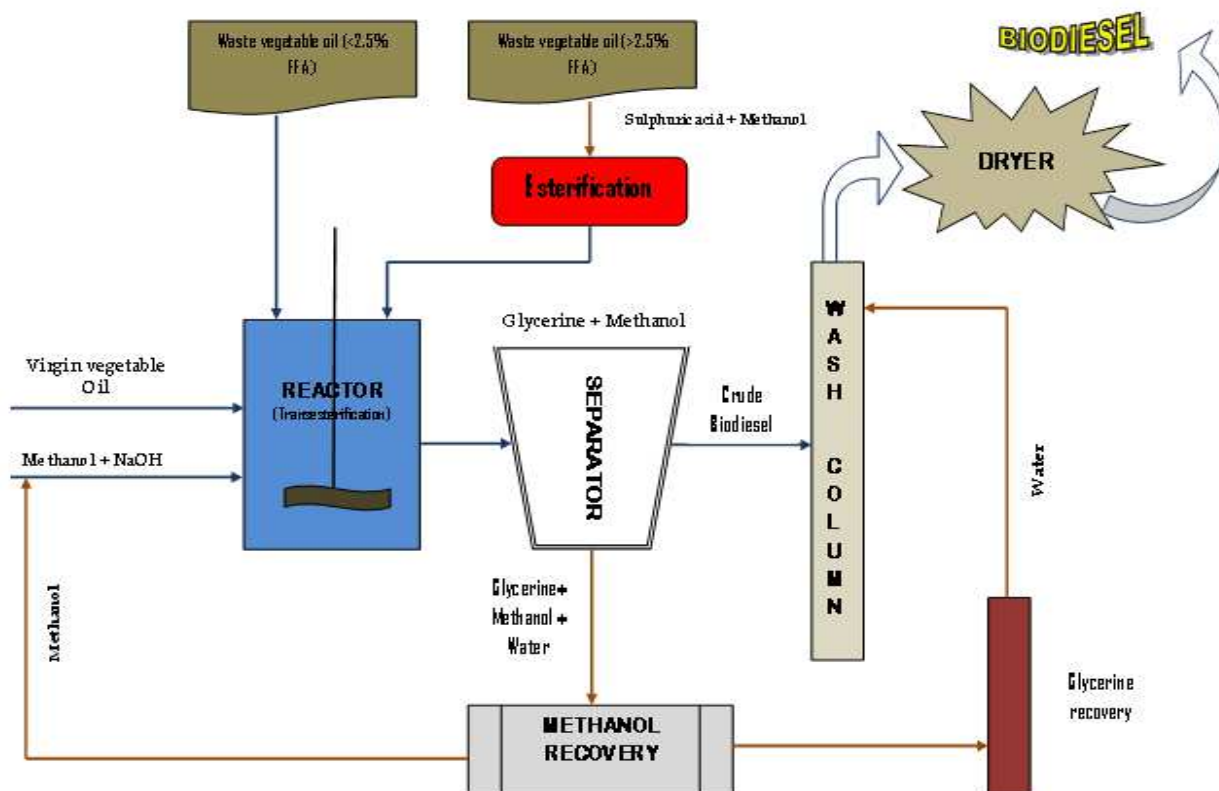
Figure 1. Process flowchart for typical biodiesel Production.

2.6. Phase Separation and Washing Procedure

The transesterification reactions produced a mixture of glycerol and methyl esters when they were completed. These, being completely insoluble with one another, separated into two distinct phases when poured into a separatory funnel. The impure glycerol settled at the bottom part of the funnel and was thus drained out by the stopper at the bottom of the separator. The quantity of the glycerol byproduct was measured using a measuring cylinder.

A sample of the biodiesel (methyl ester layer) in the flask was thereafter taken and the pH determined. If found to be caustic i.e. alkaline (say like pH 8 and above), the biodiesel in the flask was washed with hot water (about $55^{o}C$) and 0.1% acid solution. However, if found to be in normal pH range (of say like 7.0-7.5), then only warm distilled water was used in washing. The thevetia biodiesel was within normal pH range of 7.0-7.5 and hence was washed with hot water only. One third ($^1/_3$) as much hot distilled water as there is biodiesel was added in a stepwise fashion to the biodiesel in the flask. The water settles quickly at the bottom of the flask and was subsequently drained out as it settles. The washing continued in the stepwise fashion until the water settling at the bottom of the flask was visibly clear.

The biodiesel yield (% wt) after the post-treatment stage, relative to the amount of the different substrate oils poured into the flask was calculated from the equation below:

$$Biodiesel\ yield = \frac{Volume\ of\ biodoesel\ produced}{Volume\ of\ oil\ used} \times 100\%$$

2.7. Characterization of biodiesel

The parameters analysed for in the biodiesel were: Kinematic viscosity, which was determined using a calibrated Cannon-ubbelohde viscometer at a temperature of $40^{o}C$ according to ASTM D445 [15]; Flash Point, determined using a Manual Pensky-Martens closed cup apparatus according to ASTM D93 [19]; Density at $25^{o}C$, determined gravimetrically; Acid value and Percentage elemental composition (P, Ca, Na and S levels) according to the official methods of analysis described by the Association of Official Analytical Chemists [12].

3. Results

A highlight of the major steps involved in the production of biodiesel from thevetia seeds is presented in Figure 2 below. The moisture content of the milled thevetia seeds determined gravimetrically and by the moisture analyzer equipment was 6.64 + 0.01% and 6.63 + 0.05% respectively. The density of the milled biomass was $0.750g/cm^3$ and $0.881g/cm^3$ respectively. The proportion of elements in the milled biomass was: TP (0.046%), Ca (0.04%), Na (0.017%) and S (0.08%).

The percentage oil yield in the Soxhlet, Cold extraction (H-only) and Cold extraction (H/E) methods were: 62.32%, 51.87% and 45.81% respectively. Thevetia oil was observed to have a deep yellow colour and a very sweet butter smell. The result of viscosity measurement and estimation of saponification value of the oil was 21.5mm^2/s and

120.1mgKOH/g respectively. The density at 25°C and 40°C were both 0.9g/cm^3 respectively. The result of the Fatty Acid Profile (FAP) analysis revealed that thevetia oil had a rather high level of unsaturation (53.7%) (Table1). The FAP also showed that the oil's principal fatty acid constituent was oleic acid (42.3 + 0.0%).

Figure 2. Highlights of the major steps involved in the production of biodiesel from Yellow oleander fruits.

Table 1. *Fatty Acid Profile (FAP) or Percentage Fatty Acid Composition (FAC) of Thevetia Oil.*

Test parameter[a]	Name	Thevetia(%) x+S.D
C8:0	Caprylic	-
C10:0	Capric	-
C12:0	Lauric	-
C14:0	Myristic	0.19+0.01
C15:0	Pentadecanoic	-
C16:0	Palmitic	19.50+0.01
C16:1	Palmitoleic	0.25+0.01
C17:0	Margaric	0.10+0.01
C18:0	Stearic	6.39+0.01
C18:1	Oleic	42.25+0.01
C18:1-9c, 12 (OH)	Ricinoleic	0.05+0.01
C18:2	Linoleic	10.50+0.00
C18:3	Linolenic	0.50+0.01
C18:3-9c,11t, 13t	α-Eleostearic	0.01+0.01

Test parameter[a]	Name	Thevetia(%) x+S.D
C20:0	Arachidic	1.25+0.00
C20:1	Gadoleic	0.13+0.01
C20:1-11c,14(OH)	Lesquerolic	-
C20:2	Eicosadienoic	-
C20:5	Timnodonic	-
C22:0	Behenic	0.82+0.01
C22:1	Erucic	-
C24:0	Lignoceric	1.15+0.00
C24:1	Nervonic	-
Unknown	=	17.30
Total known	=	82.70
Total saturated	=	29.02
Total unsaturated	=	53.68

[a] Numbers denote the number of carbon atoms and double bonds in one molecule. For example, in Linoleic acid, 18:2 indicates that each molecule contains eighteen carbon atoms and two double bonds.

The biodiesel yield from the oils of thevetia after the transesterification reaction process was: M-only (85.2%) and M/E (78.4%) respectively. The biodiesel still maintained the colour of the parent oil but was much lighter. The results of the fuel quality parameters tested in the biodiesel is as follows: Density at 25^oC ($0.9g/cm^3$), Density at 40^oC ($0.8g/cm^3$), Kinematic viscosity ($4.7mm^2/s$), Flash point (130^oC) and Acid value ($0.4mgKOH/g$).

The proportion of elements in the biodiesel was: TP (0.001%), Ca (0.003%), Na (0.002%) and S (0.008%). Correlations between the percentage TP in the biomass and biodiesel yield from both the M-only and M/E transesterification processes are presented in Figures 3 and 4 respectively. Also, a correlation table showing the relationship between mean elemental composition and biodiesel yield is presented in Table 2 below.
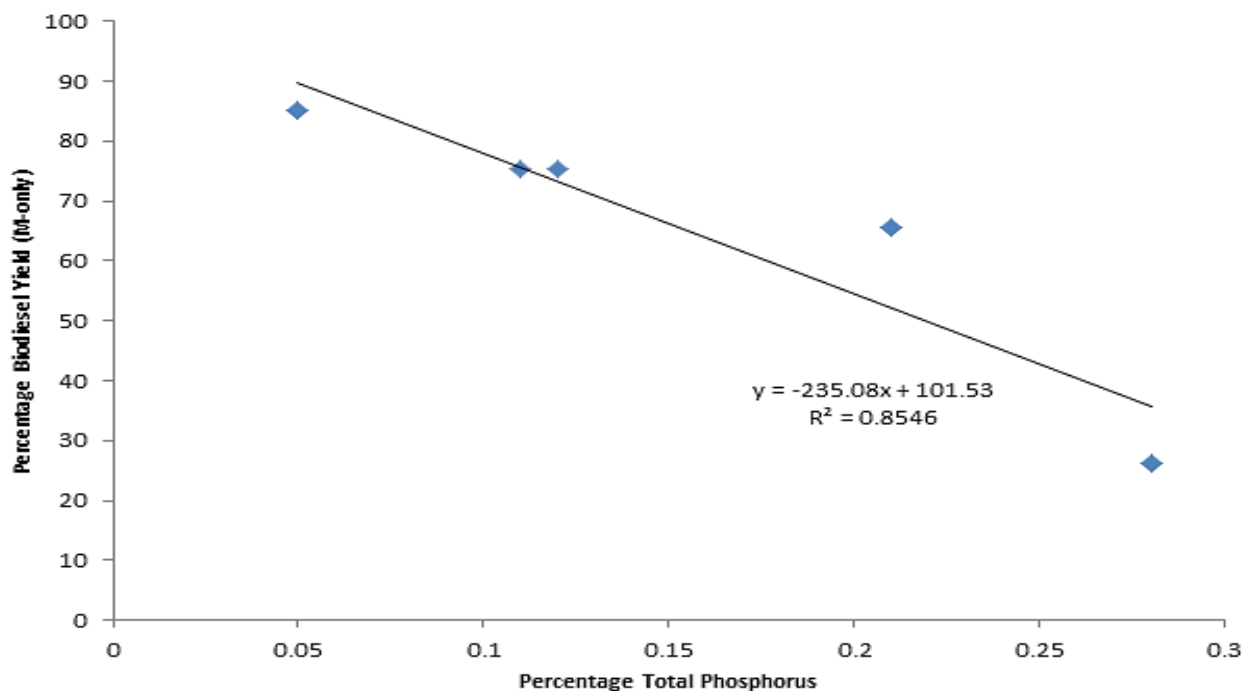

Figure 3. Relationship between percentage Total Phosphorus in biomasses and Biodiesel yield (M-only transesterification).
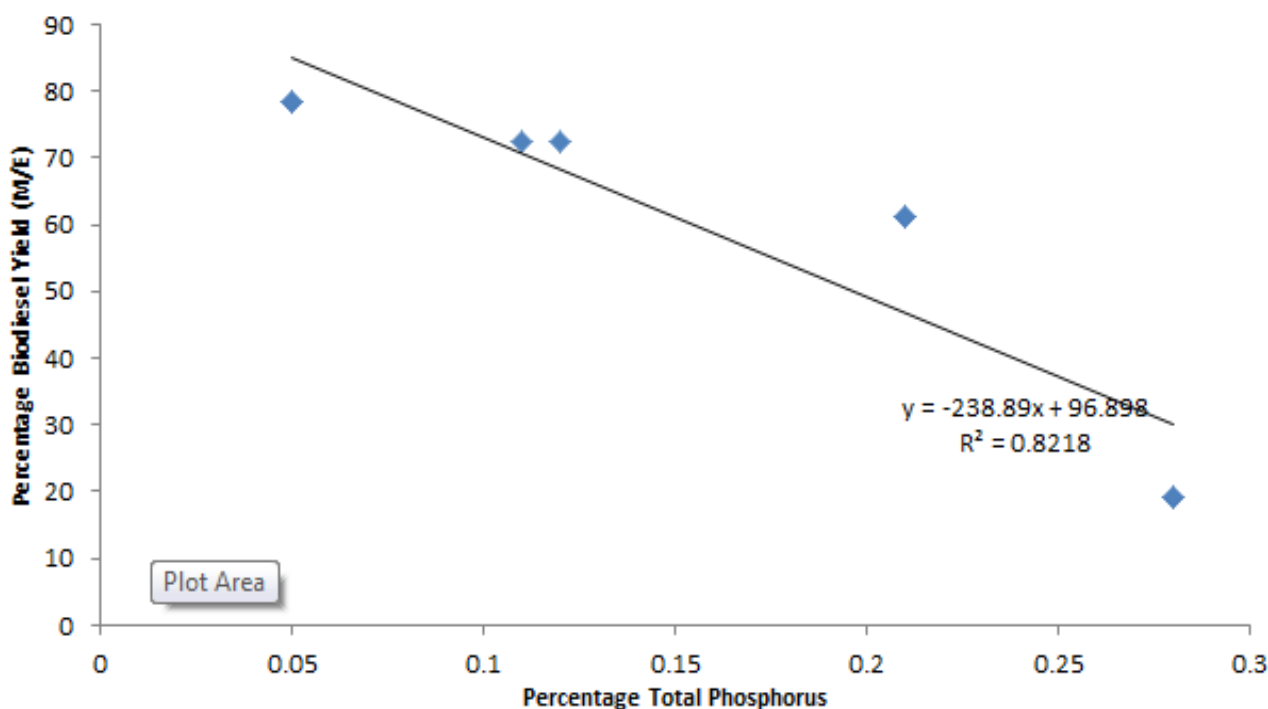

Figure 4. Relationship between percentage Total Phosphorus in biomasses and Biodiesel yield (M/E transesterification).

Table 2. Spearman correlation between mean elemental composition and biodiesel yield.

Parameter		TP (%)	Ca (%)	Na (%)	S (%)	M-only iodiesel yield (%)	M/E biodiesel yield (%)
TP (%)	Correlation coefficient	1.00					
	Sig. (2-tailed)	.					
Ca (%)	Correlation coefficient	0.79*	1.00				
	Sig. (2-tailed)	0.02	.				
Na (%)	Correlation coefficient	0.27	-0.20	1.00			
	Sig. (2-tailed)	0.52	0.64	.			
S (%)	Correlation coefficient	0.34	0.02	0.39	1.00		
	Sig. (2-tailed)	0.40	0.60	0.34	.		
M-only biodiesel yield (%)	Correlation coefficient	-0.99**	-0.80*	-0.30	-0.29	1.00	
	Sig. (2-tailed)	0.00	0.02	0.47	0.48	.	
M/E biodiesel yield (%)	Correlation coefficient	-0.99**	-0.80*	-0.30	-0.29	1.00**	1.00
	Sig. (2-tailed)	0.00	0.02	0.47	0.48	.	.

* Correlation is significant at $p < 0.05$
**Correlation is significant at $p < 0.01$

4. Discussion

The fresh milled thevetia seeds had a moisture content of $6.6 + 0.1\%$. Chindo et al [20] reported 2.2% moisture content for thevetia seed cakes, which was at slight variance with the results obtained in this work. In conventional transesterification of fats and vegetable oils for biodiesel production, water and free fatty acids always produce negative effects since the presence of these components cause soap formation, increased catalyst consumption, and reduces catalyst effectiveness.

Kusdiana and Saka [21] are of the opinion that water can pose a greater negative effect than presence of free fatty acids and hence the feedstock should be water free. Canakci and Gerpen [22] insist that even a small amount of water (0.1%) in the transesterification reaction will decrease the ester conversion from vegetable oil. That is why effort was made to properly dry the biomasses and heat the oils extracted from them for any residual water to evaporate completely. The density of the fresh milled thevetia seeds was $0.750 + 0.001 \text{g/cm}^3$.

Soxhlet extraction gave a higher oil yield in the sample when compared to that of the two Cold extraction procedures employed. The resistance to flow and shear under the forces of gravity (that is, Kinematic viscosity) of thevetia oil clearly exceed the $1.9\text{-}6.0 \text{mm}^2/\text{s}$ limit set by ASTM D6751 [10]. A high Kinematic viscosity indicates that the oil cannot be used directly in diesel engines, and there would be need for refining it. This is because oil and/or biodiesel viscosity are one of the most important properties of these liquids because it brings out a fuel's capacity to lubricate moving parts. Incorrect viscosity leads to poor lubrication, and poorly lubricated machinery can quickly break down.

The higher the unsaturation levels of oils, the greater the tendency for FFAs to cleave from their parent triglyceride molecules, thereby making the oil high FFA-containing oil. The rather high unsaturation of thevetia oil could easily predispose it to chemical degradation, and thereby cause rancidity. However, this could also imply a more reactive substrate for chemical manipulation such as in the transesterification reaction.

Saponification value, which is the number of milligrams of KOH required to neutralize the fatty acids resulting from the complete hydrolysis of 1g of fat or oil, gives an indication of the nature of the fatty acids constituent of oil and thus, depends on the average molecular weight of the fatty acids constituent of the oil. If a feedstock has a high free fatty acid (FFA) content, excess of alkali causes loss of the free fatty acids as their insoluble soaps. The resulting soaps can induce an increase in viscosity, formation of gels and foams, and make the separation of glycerol difficult. This decreases the final yield of methyl ester (biodiesel) and consumes alkali. The saponification value of the thevetia oil was considerably low as compared to an oil such as Palm Kernel Oil (PKO), which has a value of 230-254 mgKOH/g as the general saponification range for PKOs [23].

The viscosity of the biodiesel, which was $4.70 \text{mm}^2/\text{s}$, fell within the $1.9\text{-}6.0 \text{mm}^2/\text{s}$ limit of ASTM D6751[10]. The higher the viscosity of a fuel, the poorer the atomization of the fuel would be. Thus, operation of the injection would be less accurate. Moreover, at decreased temperature viscosity of the biodiesel increases [24] thereby aggravating the situation. Hence, it was observed that the biodiesel produced possesses the right viscosity to perform effectively in a diesel engine. The significant reduction ($p < 0.05$) in the viscosity from $21.50 \text{mm}^2/\text{s}$ (in the oil) to $4.70 \text{mm}^2/\text{s}$ (in the biodiesel) is an indication of the effectiveness of transesterification process in reducing the viscosity of oils.

Flash point is used in shipping and safety regulations to define flammable and combustible materials. The flash point of biodiesel is generally higher than those of petrol diesel (which is usually between 60-80°C). A minimum flash point for diesel fuel is normally required for fire safety. If methanol, with its flash point of 12°C is present in a biodiesel the flash point can be lowered considerably. The flash point of the biodiesel produced (130°C) was above ASTM D6751 [10] minimum limit. This implies that the biodiesel is safer than conventional diesel in terms of storage and transportation from the standpoint of fire hazard.

ASTM D6751 [10] stipulates 0.8mgKOH/g as the maximum limit of acid value for a biodiesel fuel. A high acid value will cause an increase in the FFA which will in turn lead to corrosion of engine parts as water is increased in the

fuel [25]. The methyl esters obtained from thevetia possessed an acid value of 0.441mgKOH/g indicating that the biodiesel underwent proper production process and has not undergone any oxidative degradation as at the time of testing.

The percentage composition of the elements-P, Ca and Na in the thevetia biomass was seen to be significantly ($p<0.05$) reduced when estimated for in the biodiesel produced thus indicating that the processing that the biomass went through for biodiesel production helped reduced the levels of these undesirable elements. Although the reduction in percentage sulphur was not significant, it was still considerably reduced below the 0.05% maximum limit set by ASTM Standard D6751 [10] in the final thevetia biodiesel produced.

5. Conclusion

The oil obtained from *Thevetia peruviana* seeds was considerably high in relation to the feedstock quantity used in the extraction process. Soxhlet extraction provided a better yield than the Cold solvent extractions. The alkaline transesterification reaction that was employed in processing the oils to biodiesel was observed to be an effective refining method as certain key parameters of the oil were significantly improved after the process.

The results of the experimental analyses carried out in this work indicate that thevetia biomass is a high-yielding and good source of oil for biodiesel production. The quality parameters of the biodiesel were found to be within international acceptable standard. However, further research into the extraction and processing of thevetia oil using other solvent mixtures is recommended to establish if, peradventure, the solvents could prove to be more effective than the ones explored in this work.

Acknowledgements

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