Nigerian Research Journal of Engineering and Environmental Sciences 2(1) 2017 pp. 65-73

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

Original Research Article

EVALUATION OF AFRICAN OIL BEAN (*PENTACLETHRA MACROPHYLLA* BENTH) SEED OIL AS POTENTIAL FEEDSTOCK FOR BIODIESEL PRODUCTION

***Osarumwense, J.O., Oti, E.O. and Erhaghewu, J.E.**

Department of Science Laboratory Technology, Faculty of Life Sciences, University of Benin, Benin City, Nigeria
*judeosarumwense@uniben.edu

ARTICLE INFORMATION

Article history:
Received 20 January 2017
Revised 27 January 2017
Accepted 31 January 2017
Available online 01 June 2017

Keywords:
Pentaclethra macrophylla
Feedstock
Transesterification
Biodiesel
Viscosity

ABSTRACT

The global climate crises arising from the negative effect of emissions from the combustion of fossil fuels has led to the search for environmentally friendly alternatives. In this study, the oil extracted from African oil bean (Pentaclethra macrophylla Benth) seeds was investigated as a feedstock for the production of biodiesel. The oil was extracted from the seeds in a soxhlet extractor using n-hexane as the extracting solvent. The acid value, free fatty acid, density and viscosity of the oil were then determined. The oil was pretreated and transesterified using sodium hydroxide as catalyst to produce biodiesel. The results obtained showed that the extraction process resulted in a yield of 36.58% of oil. The acid value, free fatty acid, density and viscosity of the oil obtained were 3.37 mgKOH/g, 1.68%, 0.915 g/cm^{3}and 8.92 mm^2/s respectively. The yield of biodiesel was obtained as 69%. The characterisation of the biodiesel produced revealed that the acid value (0.4107 mgKOH/g), viscosity (3.782 mm^2/s), flash point (132 ^{o}C) and density (0.8676 g/cm^3) were within the standard specified by the ASTM D6751. This is an indication that oil obtained from P. macrophylla oil could be used as feedstock for biodiesel production.

1. INTRODUCTION

Emissions from fossil fuels have been reported as one of the leading anthropogenic sources of greenhouse gases. This has resulted in a wide variety of problems such as global warming, ozone layer depletion and rising of sea levels (Meinshausen et al., 2009). The growth in the world's transportation sector has caused an increase in fuel and energy demand. This demand has been largely satisfied by non-renewable sources of energy, particularly crude oil or

petroleum (Aransiola et al., 2012). Biodiesel is an alternative to petroleum-based diesel. It has low emission profiles and is environmentally friendly because of its biodegradability and non-toxicity (Ding et al., 2011; Demirbas 2009). Biodiesel is made from renewable sources such as vegetable oils, animal fats and recycled grease. The feedstock for biodiesel production contains triglycerides, free fatty acids (FFA), and other contaminants depending on the degree of pretreatment received prior to deliver (Ma et al., 1999). Based on the amount of FFA contained in it, biodiesel feedstock can be classified as refined vegetable oils (< 0.5%), crude vegetable oil (0.5-5%), used cooking oil (2-7%) and animal fat (10-30%). It has been established that the FFA content of vegetable oils for producing biodiesel should be as low as possible; preferably below 0.5% (Ma et al., 1999).

African oil bean (*P. macrophylla*) is a multipurpose tree from Africa with potentials for agro forestry in the tropics. It is the sole member of the genus occurring naturally in the humid lowlands mostly in the southern rain forest zone of West Africa. The raw seed is a potential source of edible protein and calories containing amino acids and essential fatty acids (Enujiugha and Agbede, 2000). The *P. macrophylla* seeds could serve as supplementary source of essential nutrients for man and livestock provided the anti-nutrients inherent in the seeds are adequately detoxified to least significant levels (Balogun, 2013). The physico-chemical evaluation of the oil has shown that it has no irritating odour; but it had high peroxide and saponification values (Akindahunsi, 2004).

It has been reported that the sources of oils and fats is diminishing and this has led to a growing need for the search for new sources (Kazadi et al., 2011). In Nigeria, the demand for vegetable oils has been on an ever-increasing trend as industrialists rely mostly on the popular oils like palm oil, palm kernel oil, groundnut oil and coconut oil for the production of various products (Akintayo, 2004). Nigeria, being a tropical country, has wide variations in climatic conditions and therefore has a wide variety of domestic plants from which oil can be extracted. These plants range from the largely known and highly utilised ones like soybean, palm kernel, groundnut to under-utilised ones like walnut, locust bean, castor oil bean, African oil bean, grape seed, rice bran and macadamia nut (Akindahunsi, 2004). However, many researchers have analysed the nutritional and pharmaceutical values of *P. macrophylla* oil but a search of the literature has shown that the oil has not been evaluated as a feedstock for producing a biofuel like biodiesel. Therefore, the aim of this study was to investigate the potentials of *P. macrophylla* oil as a feedstock for the production of biodiesel.

2. MATERIALS AND METHODS

2.1. Material Collection and Preparation of Samples

The *P. macrophylla* seeds were obtained from Oregbeni market in Benin City, Edo State of southern Nigeria. The fruits were first dehulled and then sliced into smaller bits. The sliced seeds were sun dried for about 7 hours and then oven dried (Heraeus T6000 model) at 90°C to constant weight (Al-Harbawy and Al-Mallah, 2014). The dried seeds were then ground into powder using domestic blender (model JBL2102), sieved to obtain particle size of <500μm and stored in a corked polyethylene bottle. All reagents used in this work were of

analytical grade, and obtained from Pyrex-IG scientific company, Benin City, Edo State, Nigeria.

2.2. Extraction of oil from *P. macrophylla* Seeds

The extraction of oil was carried out using n-hexane in a soxhlet extractor according to the method of Akpan *et al*., (2006). A measured amount of the sample (100 g) was placed in the thimble in the extraction chamber of the soxhlet apparatus, and 500 cm^3 of n-hexane was added to the round bottom flask. The soxhlet apparatus was heated to 70ºC and the extraction process was allowed to run for 3 hours. The oil-solvent mixture was transferred to a rotary evaporator for solvent recovery. The remaining traces of solvent were removed by heating the flask containing the oil in a water bath. The percentage yield of oil was calculated using Equation (1).

$$\% \ Yield = \frac{w_i - w_f}{w_i} \times 100 \quad (1)$$

Where W_i= initial mass of ground seed, and W_f= final mass of ground seed.

2.3. Production of Biodiesel from *P. macrophylla* Oil

The high free fatty acid (FFA) content of oil was first reduced below 0.5% by using acid-catalyzed esterification. A certain weight of oil (100g) was heated in a biodiesel reactor at 60°C for 30 minutes. A mixture of concentrated sulphuric acid (0.84g) and methanol (20:1 methanol to oil molar ratio) was added to the oil. The mixture was agitated for 60 minutes and allowed to settle in the reactor for 12 hours, resulting in three phases. The top layer contained of unreacted methanol, the middle layer contained oil and fatty acid methyl ester (FAME), while the bottom layer contained water (by-product of the reaction) (Van-Gerpen *et al.*, 2004). The middle layer was collected, weighed and used for transesterification making use of alkali atalysis. The pretreated oil (87.3g) was heated in the biodiesel to a temperature of 65°C, then a mixture of NaOH (0.87g) and methanol (6:1 methanol to oil molar ratio) was added. The mixture was agitated for 90 minutes, allowed to settle in the reactor for 3 hours, and separated into two phases. The top, less dense phase rich in FAME and the bottom, denser phase rich in glycerol were separated. The FAME-rich phase was collected and purified by hot water treatment (Mathiyazhagan et al., 2011).

2.4. Characterisation of *P. macrophylla* Oil and Biodiesel

Standard procedures according to the American oil chemists' society (AOCS, 1990) and American society for testing and materials (ASTM) methods of analysis were adopted in the characterisation of the raw oil and the biodiesel produced.

2.4.1. Moisture content

A certain amount of the sample (50 g) was weighed and dried in an oven at 80°C for 2 hours. The sample was removed from the oven and placed in a desiccator for 30 minutes to cool.

The sample was then reweighed. The procedure was repeated several times until a constant weight was obtained. The percentage moisture content of the seed was calculated from Equation (2).

$$Moisture\ content\ (\%) = \frac{(w_o - w_d)}{w_o} \times 100 \tag{2}$$

Where W_o is original weight of the sample before drying and W_d weight of sample after drying (Shridhar *et al*., 2010).

2.4.2. Acid value and free fatty acid (FFA)

The acid value and FFA of the oil were determined according to the Equations (3) and (4) respectively as described by Wu and Leung (2011) and Rukunudin *et al*. (1998).

$$Acid\ value = \frac{(A-B) \times N \times 56.1}{W} \tag{3}$$

Where A = volume of KOH needed to neutralize sample, B = volume of KOH needed to neutralize blank, N = normality of KOH solution, W = weight of sample in grams

$$\%FFA = \frac{(A-B) \times N \times MW(fatty\ acid)}{10 \times W} \tag{4}$$

2.4.3. Determination of density

A clean and dry pycnometer (density bottle) of 25 cm^3 capacity (V_L) was weighed (M_B) and then filled with the sample. The bottle was stoppered, and reweighed to give M_{BL}. The density of the samples was taken at 30^{o}C as expressed in Equation (5).

$$D = \frac{M_{BL} - M_B}{V_L} \tag{5}$$

where D is density of liquid (g/cm^3); M_{BL} , the mass of bottle and liquid (g); M_B, the mass of bottle only (g) and V_L is the volume of the liquid (cm^3) (Aworanti et al., 2012).

2.4.4. Determination of viscosity

The viscosity of the biodiesel was carried out using Brookfield digital viscometer (model LVDV-I). A measured amount of the sample (20 cm^3) was dispensed into a cup holder, and the temperature was set at 40 ^{o}C. The spindle was immersed into the liquid to the level of the calibrated mark of the spindle and then the speed was set at 30 rpm. After 20 minutes, the value of the viscosity was recorded. The Brookfield digital viscometer measures dynamic viscosity of fluid. Hence, the viscosity was converted to kinematic viscosity by dividing with density of fluid (Nita and Geaca, 2012).

2.4.5. Determination of flash point

The flash points were measured with a pensky-martens closed cup tester (model K16200). The sample container was rinsed with the sample to be tested. The cup was filled with the sample to the mark and then placed into the cup compartment in the flash point tester. The thermometer was then inserted into the tester. The equipment was switched on and the sample in the tester was stirred for three minutes. The ignition source was then turned on, and the flashing was observed at every 10 ^{o}C rise in temperature. The temperature at which the biodiesel flashed (ignited) was recorded (Nita and Geaca, 2012).

3. RESULTS AND DISCUSSION

The physico-chemical analyses of *P. macrophylla* seed oil revealed the following properties presented in Table 1.

Table 1: Properties of *Pentaclethra macrophylla* seed oil

Properties	*P. macrophylla* seed oil	Reported values in literature	Reference
Moisture content of seed (%)	8.09	5.70	Igwenyi *et al.* (2015)
Oil content (%)	36.58	35.08; 47.9; 53.6	Okoye (2016); Ikhuoria *et al.* (2008); Akindahunsi, (2004).
Colour	Light brown	Light brown	Ikhuoria *et al.* (2008)
Density (g/cm^3)	0.915	0.8615	Kazadi *et al.* (2011)
Viscosity @ 40℃ (mm^2/s)	8.92	-	-
Acid value (mgKOH/g)	3.37	3.25±0.20; 1.23; 2.81; 5.31 ±0.54	Ikhuoria *et al.* (2008); Okoye (2016); Akubugwo *et al.* (2008), Kazadi *et al.* (2011)
Free fatty acid (%)	1.68	1.64±0.13 1.40±0.01	Ikhuoria *et al.* (2008), Ugbogu and Akukwe (2009)

The result obtained for the percentage moisture content of the seed, 8.09%, is higher than the 5.70% recorded in the work of Igwenyi *et al.* (2015). The variation in moisture content could have resulted from the difference in the variety of seeds used, the location and period of collection of the seeds. The percentage oil yield of *P. macrophylla* seed was 36.58%. This value is much higher than the oil yield of some common sources of oils such as soybean (18 to 22%), canola (22%), olive (17%), cannabis (30.5 %) and corn oil (3.1 to 5.7 %) (Gonabad *et al.*, 2015). It also compares favourably with some other commercial oil plants such as cotton seed (36%), sesame (44%), groundnut (40%), sunflower (44%) and palm kernel 40% (Evwierhoma. and Ekop 2016). Ikhuoria *et al.* (2008) has suggested that processing of the oil from *P. macrophylla* seed for commercial purposes could be an economically attractive venture because of the large amount of oil the seed contains. Studies have also shown that the mode of extraction, the effect of the solvent on oil extraction, temperature and time of extraction are very important operational parameters, which have significant impact on the yield of oil (Gonabad *et al.*, 2015). *P. macrophylla* oil has a density of 0.8915g/cm^3 at 30^{o}C and this value is within the range of most of the seed oils recorded in literature. Kazadi *et al.* (2011) stated that the density suitable for edible oils range from 0.88 to 0.94 g/cm^3 but for fuel usage, it ranges from 0.82 to 1.08 g/cm^3. The acid value and free fatty acid of *P. macrophylla* oil are 3.37 mgKOH/g and 1.69% respectively. This acid value is higher than

1.23, 2.81 and 3.25 ±0.20mgKOH/g obtained by Okoye (2016), Akubugwo *et al.* (2008) and Ikhuoria *et al.* (2008) respectively but much lower than 5.31 ±0.54 mgKOH/g obtained by Kazadi *et al.* (2011). The acid value of oil is the amount (mg) of potassium hydroxide required to neutralise the free acid in 1 g of the sample (Akindahunsi, 2004). Free acid can stimulate oxidation of oils by enzymatic or chemical means to form off-flavour component (Ikhuoria *et al*., 2008). The acid value of *P. macrophylla* oil is reasonably low; indicating that the oil is a quality feedstock for the production of biodiesel.

The transesterification of *P. macrophylla* oil gave a biodiesel yield of 69% and Table 2 shows the physico-chemical properties of the biodiesel produced in comparison with the specifications of international standards for biodiesel. The fuel properties tested were within the acceptable range specified by international standards (ASTM D6751 and EN14214) as stated in Moser (2009).

Table 2: Characteristics of *P. macrophylla* oil-based biodiesel and specifications of international standards

Properties	*P. macrophylla* oil-based biodiesel	ASTM D6751	EN 14214
Density (g/cm^3)	0.8676	--	0.86-0.9
Viscosity @ 40℃ (mm^2/s)	3.782	1.9-6.0	3.5-5.0
Flash point (^{o}C)	132	130 minimum	101 minimum
Acid value (mgKOH/g)	0.4107	0.8 maximum	0.5 maximum

The flash point of *P. macrophylla* oil-based biodiesel was 132 ^{o}C. This value fell within the acceptable limit as shown in Table 2. The flash point is the lowest temperature at which the vapour of a combustible liquid can be made to ignite (flash) in air on application of an ignition source. It is related to the ignitability of a fuel (Audu et al., 2013). Flash point is an indication of unreacted alcohol remaining in the finished fuel. It is the requirements for the safety precautions involved in fuel handling, storage and fire regulations (Prugh, 2007). The density (0.8676 g/cm^3) and acid value (0.1407 mgKOH/g) of the biodiesel produced were within the acceptable limits. The viscosity of the biodiesel was 3.782 mm^2/s. This value is adequate for diesel engine. Viscosity is one of the major characteristics required to ascertain the quality of biodiesel. The higher the viscosity, the greater is the tendency for the fuel to form engine deposits and a low viscosity can lead to excessive internal pump leakage ((Aworanti, et al., 2012; Babu and Venkata 2012). Transesterification of vegetable oil reduces the molecular weight and viscosity of the oil, and improve its volatility to a suitable range for diesel engines (Aworanti et al., 2012).

In this work, the viscosity, density and acid value of the *P. macrophylla* oil significantly reduced from 8.192 to 3.782 mm^2/s, 0.915 to 0.8676 g/cm^3 and 3.370 to 0.411 mgKOH/g respectively after the transesterification process. Figure 1 shows the comparison of the properties of *P. macrophylla* oil (raw) and *P. macrophylla* oil-based biodiesel.

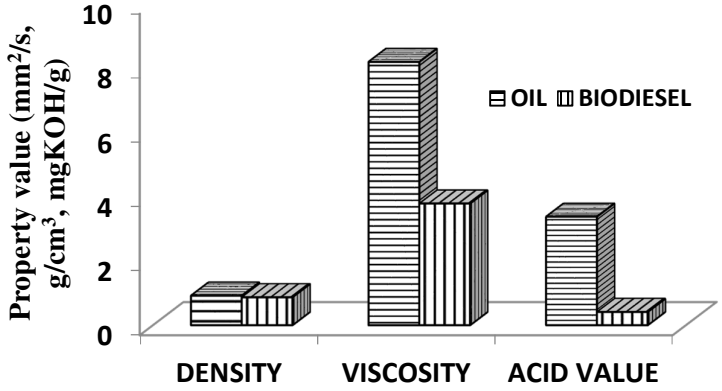

Figure 1: Properties of raw oil and *P. macrophylla* oil-based biodiesel

4. CONCLUSION

The results of this work have revealed that *P. macrophylla* seeds contain 36.58% oil. The transesterification of *P. macrophylla* oil gave 69% yield of biodiesel. The viscosity, density and acid value of the oil reduced with about 53%, 5% and 87% respectively after the transesterifcation of the raw oil. All properties of biodiesel tested are within the specifications of international standards. Therefore, oil extracted from *P. macrophylla* seeds can be exploited for the production biodiesel.

5. ACKNOWLEDGMENT

The authors wish to acknowledge the assistance and contributions of the laboratory staff of Department of Chemical Engineering and Department of Plant Biology and Biotechnology (PBB), University of Benin, Benin City toward the success of this work.

6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

Akindahunsi, A.A. (2004). Physicochemical studies on African oil bean (*Pentaclethra macrophylla* Benth) seed. *Journal of Food, Agriculture and Environment,* 2(3-4), pp. 14-17.

Akintayo, E. T. (2004). Characteristic and composition of *Parkia biaglobbosa* and *Jatropha curcas* oil and seeds. *Bioresource Technology*, 92, pp. 307-310.

Akpan, U. G., Jimoh, A. and Mohammed, A. D. (2006). Extraction, characterization and modification of castor seed oil. *Leonardo Journal of Sciences,* 8, pp. 43-52.

Akubugwo I. E, Chinyere G. C. and Ugbogu A. E. (2008). Comparative studies on oils from some common plant seeds in Nigeria. *Pakistan Journal of Nutrition,* 7(4), pp. 570-573.

Al-Harbawy, A. W. and Al-Mallah, M. K. (2014). Production and Characterization of Biodiesel from seed oil of Castor (*Ricinus communis L.*) plants. *International Journal of Science and Technology,* 3(9), pp. 508-513.

AOCS (1990). *Official Methods of analysis of the American Oil Chemists' Society*, edited by Helrich, K., 15th ed., vol. 2, Association of official Analytical Chemists, Vergina, USA.

Aransiola, E. F., Daramola, M. O., Ojumu, T. V., Aremu, M. O., Layokun, S. K. and Solomon, B.O. (2012). Nigerian *Jatropha Curcas* Seeds Oil: Prospect for Biodiesel Production in Nigeria. *International Journal of Renewable Energy Research,* 2(2), pp. 83-89

ASTM (2008). *An Overview of ASTM D6751*: *Biodiesel Standards and Testing Methods*. Edited by Burton, R. Alternative Fuels Consortium, Central Carolina Community College Piedmont Biofuels, Carolina, USA.

Audu, T.O.K. Aluyor, E.O. Egualeona, S. and Momoh, S. S. (2013). Extraction and Characterization of *Chrysophyllum albidum* and *Luffa cylindrica* Seed Oils. *Petroleum Technology Development Journal,* 3(1), pp. 1-7

Aworanti, O.A. Agarry, S. E. and Ajani, A. O. (2012). A Laboratory Study of the Effect of Temperature on Densities and Viscosities of Binary and Ternary Blends of Soybean Oil, Soy Biodiesel and Petroleum Diesel Oil. *Advances in Chemical Engineering and Science,* 2, pp. 444-452.

Babu P. S. and Venkata R. M. (2012). Significance of biodiesel use as I.C. engine fuels. *International Journal of Advanced Engineering Research and Studies,* 1(2), pp.40-43.

Balogun, B.I. (2013). Evaluation of the Nutritional Potentials of Fermented Oil Beans Seed *Pentaclethra macrophyllah* Benth. *Production Agroculturer Technonlogy,* 9(2), pp. 73-87

Demirbas, A., (2009). Progress and recent trends in biodiesel fuels. *Energy Conversion and Management,* 50, pp. 14-34.

Ding, J., He, B. and Li, J. (2011) Biodiesel Production from Acidified Oils via Supercritical Methanol. *Energies*, 4, pp. 2212-2223.

Enujiugha, V. N. and Agbede, J. O. (2000). Nutritional and anti-nutritional characteristics of African oil bean (*penaclethra macrophylla*) seed. *Applied Tropical* Agriculture, 5, pp. 11-14.

Evwierhoma E. T. and Ekop I. E (2016). Extraction and Characterization of oils from local seeds. *International Journal of Scientific & Engineering Research*, 7(5), pp.1280-1294

Gonabad, M.A., Noghabi, M. S. and Niazmand, R. (2015). Evaluation of Extraction Percentage and Physicochemical Properties of Walnut Oil. *Journal of Applied Environmental and Biological Sciences,* 4, pp.74-82.

Igwenyi, I. O. Isiguzo, O. E. Aja, P. M. Ugwu Okechukwu, P. C. Ezeani N. N. and A.J. Uraku (2015). Proximate Composition, Mineral Content and Phytochemical Analysis of the African Oil Bean (*Pentaclethra macrophylla*) Seed. *American-Eurasian Journal of Agriculture and Environmental Science,* 15(9), pp.1873-1875.

Ikhuoria, E. U., Aiwonegbe, A. E., Okoli, P. and Idu, M. (2008).Characteristics and composition of African oil bean seed (*pentaclethra macrophylla* benth). *Journal of Applied sciences,* 8(7), pp.1337-1339.

Kazadi M., Kaaya, A. N., Kansiime, F., Tabuti, J. R.S. and B. Samvura (2011). Oil content and physicochemical characteristics of some wild oilseed plants from Kivu region Eastern Democratic Republic of Congo. *African Journal of Biotechnology,* 10(2), pp.189-195.

Ma, F., Clements, L. D., and Hanna, M. A. (1999). The effect of mixing on transesterification of beef tallow. *Bioresource Technology,* 69, pp. 289–93.

Mathiyazhagan, M., Ganapathi, A., Jaganath, B., Renganayaki, N. and Sasireka, N. (2011). Production of Biodiesel from Non-edible plant oils having high FFA content. *International Journal of Chemical and Environmental Engineering*, 2(2), pp.119-122

Meinshausen, M., Meinshausen, N., Hare, W., Raper, S. C. B., Frieler, K., Knutti, R., Frame, D. J. and Allen, M. R. (2009). Greenhouse gas emission targets for limiting global warming to 2°C. *Nature* 458, pp. 1158 – 1162

Moser, B.R. (2009). Biodiesel production, properties, and feedstocks. *In vitro Cell Development,* 45, pp. 229-266

Nita I. and Geaca S. (2012). Study of density and viscosity for ternary mixtures biodiesel, diesel fuel, and bio-alcohols. *Ovidius University Annals of Chemistry,* 23(1), pp. 58-62

Okoye, E.I. (2016). Extraction, characterization and pharmaceutical screening of oil obtained from seeds of *Pentaclethra macrophylla* benth (African oil bean seed). *The Pharmaceutical and Chemical Journal,* 3(2), pp. 88-91

Prugh, W.R. (2007). The relationship between flash point and LFL with application to hydrid mixture. In: Proceedings of the 41st annual loss prevention symposium, American Institute of Chemical Engineers, April 22-26, Houston, Texas, USA.

Rukunudin, I.H., Whitea, P.J., Bern, C. J. and Bailey, T. B. (1998). A Modified Method for Determining Free Fatty Acids from Small Soybean Oil Sample Sizes. *Journal of American Oil and Chemical Society*, 75(5), pp. 563-568

Shridhar, B.S., Beena, K. V., Anita, M. V and Paramjeet, K. B. (2010). Optimization and Characterization of Castor Seed Oil. *Leonardo Journal of Sciences,* 17, pp. 59-70

Ugbogu O.C. and Akukwe A. R. (2009). The antimicrobial effect of oils from *Pentaclethra macrophylla* Bent, *Chrysophyllum albidum* G. Don and *Persea gratissima* Gaerth F on some local clinical bacteria isolates. *African Journal of Biotechnology,* 8(2), pp. 285-287

Van-Gerpen J., Shanks B., Pruszko R., Clements D. and Knothe G. (2004). *Biodiesel Analytical Methods*. NREL/SR-510-36240. Available electronically at http://www.osti.gov/bridge.

Wu, X. and Leung, D. Y. C. (2011). Optimization of biodiesel production from camelina oil using orthogonal experiment. *Applied Energy,* 88(11), pp. 3615-3624.