Global Research Journals Vol. 1(1) pp.001 - 013 July 2011
Available online http://www.globalresearchjournals.org/?a=journal&id=jcms

Full Length Research.

Comparative Study of the properties of biodiesel prepared from *Jatropha curcas* oil and palm oil

M. A. OMOTOSO, M. J. AYODELE and A. O. AKINTUDIRE

Chemistry Department, University of Ibadan, Ibadan,Nigeria.

Corresponding Author's E-mail:beckyomot@yahoo.com

Accepted 10th January 2011

Oil was extracted from *jatropha curcas* seeds and palm fruits fronds (*Elaeis guineensis*). Upon extraction, the oils were characterized using standard methods. The percentage oil yields were 60.4% and 35.1% respectively for *jatropha carcus* seeds and palm fruits.Two steps homogeneous base catalyzed trans-esterification process was adopted for the production of the biodiesels. The first step was the acid esterification reaction, in which methanol and 2% w/w of sulphuric acid (catalyst) was used at 65°C for 5hours. The second step involved a base trans-esterification reaction where potassium hydroxide was the catalyst at 65°C for 3hours. The percentage yield of the biodiesel from *jatropha curcas* oil and palm oil were 75.3% and 63.6% respectively. The physico-chemical parameters for the prepared biodiesel were determined and compared with ASTM D6751 and EN14214 biodiesel standards. The properties of *Jatropha Curcas* biodiesel were closer to the biodiesel specifications of the international standards.The quality and extent of fatty acids conversion to their fatty acids methyl esters (FAME) derivative was determined by subjecting the two vegetable oils and their biodiesel as well as petroleum diesel to GC-MS analysis. *jatropha curcas* and palm biodiesels were found to contain a total of 10 and 13 FAME respectively.

Keywords: *jatropha curcas*, palm oil (*Elaeis guineensis*), trans-esterification, physico-chemical, GC-MS analysis.

INTRODUCTION

The general increasing rate of fuel and energy prices and the impact of environmental pollution of increasing exhaust emissions, ginger researchers to focus attention to developing alternative energy resources, such as biodiesel fuel to replace the conventional petroleum fuel. Biodiesel is a monoalkyl ester of fatty acids derived from vegetable oils or animal fats. Vegetable oil is also seen as a promising alternative because it has several advantages. It is renewable, biodegradable, environmentally-friendly and produced easily in rural areas, where there is an acute need for modern forms of energy (Boehman, 2005; Shaheed and Swain, 1998). Therefore, in recent years several researches have been focused on the use of vegetable oils as a source of biodiesel to fuel engines (Pramanik, 2003; Bozbas, 2008). Furthermore, vegetable oil-based products hold great potential for stimulating rural economic development because farmers would benefit from increased demand for vegetable oils. Various vegetable oils, including palm oil, *jatropha* oil, soybean oil, sunflower oil, rapeseed oil, and canola oil have been used to produce biodiesel fuel and lubricants (Emil et al., 2009). However, the major challenges have been the food and land use competitiveness for some of these oils.

Biodiesel is usually produced by the trans-esterification of vegetable oils or animal fats with methanol or ethanol (Freedman et al., 1986; Noureddini and Zhu, 1997; Schuchardt et al., 1998, Fukudal et al., 2001; Du et al., 2004 and Knothe et al., 2006). It has many advantages. It is renewable and safe to use in all conventional engines. It offers the same performance and durability as petroleum diesel fuel. It reduces tailpipe emissions, visible smoke, noxious fumes and odors. In addition, it is non-flammable and non toxic.

Various types of fatty acids present in the oil have different effects on the physical properties of the biodiesel produced from it. Saturated fatty acids have positive effects on the cetane number and the oxidation stability it. But it does not make it stable in a cold environment. Contrary to this, polyunsaturated fatty acids in the oil used to prepare the biodiesel make it stable in cold weather but is vulnerable to oxidation. Short chain fatty acids have a negative effect on the flash point. Long chain fatty acids

are in obvious rejection to the biodiesel industry as it increases the viscosity of the
biodiesel in cold weather (Knothe et al., 2001). The appropriate fats and oils are selected through accessing their physical and chemical properties.

The use of biodiesel has grown dramatically during the last few years. However, feedstock costs account for a large percent of the direct biodiesel production costs, including capital cost and return (Bozbas, 2008).

One way of reducing the biodiesel production costs is to use less expensive feedstock such as inedible oils, animal fats, waste food oil and by products of the refining vegetables oils that contain fatty acids The availability and sustainability of sufficient supplies of less expensive feedstock will be a crucial determinant delivering a competitive biodiesel to the commercial filling stations. Fortunately, inedible vegetable oils, mostly produced by seed-bearing trees and shrubs can provide an alternative. With no competing food uses, this characteristic turns attention to *Jatropha curcas*, which grows in tropical and subtropical climates across the developing world (Openshaw, 2000).

It was reported in the literature that the oil content of *jatropha carcus* seed was high (66.4%). Triacylglycerol and linolenic acid were respectively the dominant lipid species fatty acid while the major triacyglycerol was 1,2-Dioleoyl-3-linoleoyl-rac-glycerol in the oil. Ten sterols and thirteen triterpene alcohol were identified in the unsaponifiable fraction of the oil (Adebowale and Adedire, 2006).

The major byproduct of biodiesel production is glycerol, its uses is enormous. Glycerol can be thermo-chemically converted into propylene glycol, 1,3-propanediol, lipids and several other chemicals (Kumar and Sharma, 2008). Among lipids, it was shown that glycerol can be used to produce docosahexaenoic acid (DHA) through fermentation of the alga *Schizochytrium limacinum.* It also finds useful application as key ingredient in the manufacture of explosives (Solomon, 1996).

This study was undertaken to evaluate and compare the quantity and quality of the biofuels produced from *jatropha curcas* seeds and palm fruits and also to ascertain that their physico-chemical characteristics were comparable with that of conventional petroleum based diesel and ASTM D6751 and EN14214 standards.

MATERIALS AND METHODS

Collection of the *Jatropha Carcus* seeds and palm fruits

Jatropha seeds were sourced locally from Okitipupa in Ondo state, Nigeria. The seeds were identified at the Botanical Garden of the University of Ibadan after which they were sorted out to remove foreign particles. This was followed by cleaning, deshelling and drying. The dried seeds were then crushed and grounded to increase the surface area. The fresh palm fruits on the other hand, were gotten from a farm in Ibadan, Nigeria.

Extraction of the oil

Grounded *Jatropha carcus* seeds were weighed and defatted in a soxhlet apparatus using n-hexane at 60˚C. The hexane was removed from the oil by distillation under reduced temperature and pressure. The crude *Jatropha carcus* oil was labeled JAT1.

The crude palm oil was extracted the same day from the fruits using rending method. The fruits were removed from the fronds, weighed and boiled in water for two hours after which the water was drained off. The boiled fruits were mashed and boiled with water. The fleshy mesocarp and the kernel were separated from the oil and water mixture by sieving. The mixture of the oil and water was reboiled until the oil palm formed on the surface. The palm oil was then collected from the top layer. The crude palm oil was labeled PAM1.

Preparation of the biodiesel

The two-step trans-esterification process was used. The first step was the acid esterification reaction where methanol was used as the alcohol and 2%v/v concentrated H_2SO_4 was the catalyst. Methanol was measured based on the oil to methanol mole ratio 1:6 into a flask. 2% w/w of concentrated sulphuric acid was added. The methanol sulphuric acid mixture was shaken thoroughly until a homogeneous mixture was obtained. This mixture results into an initial reaction of sulphuric acid and methanol to give methoxide, which then goes into reaction with the oil. JAT1 was measured according to oil to methanol ratio 1:6. The oil was preheated to 65^{o}Cin a flask coupled with a thermometer in which the reaction is carried out and then the methanol- sulphuric acid mixture was added into the flask. A magnetic stirrer was used to mix the resulting mixture maintaining the temperature at 65^{o}C and refluxed under this condition for three hours. The resulting system was poured into a separating funnel and left overnight for separation to occur.

Two distinct layers were obtained after separation has taken place. The biodiesel intermediate, (JAT2), formed the top golden brown clear layer. The bottom layer is glycerol. JAT2 was washed several times with warm distilled water to remove excess methanol, catalyst, glycerol and any soap that would have formed during the reaction.

JAT2 and methanol were measured based on 1:6 ratio separately. 1.5%w/w potassium hydroxide (KOH) was added to the measured methanol in the flask. The KOH was allowed to dissolve in the methanol to obtain a homogeneous mixture. The measured JAT2 was preheated to 65^{o}C and added to the methanol – KOH mixture. The resulting system was refluxed for three

hours at 65°C and stirring with a magnetic stirrer. The mixture was allowed to stand overnight. Two distinct layers were obtained. The top layer was the biodiesel, JAT3 while the bottom layer was glycerol. JAT3 was washed with warm distilled water several times to remove excess methanol, KOH, glycerol and any soap that would have formed during the reaction.

The above procedure was similarly carried out on palm oil (PAM1) to obtain the intermediate PAM2 and biodiesel PAM3.

The above two step trans-eterification reaction can be represented as follows:

$$\text{Triglyceride} + 3\text{ROH} \xrightarrow{\text{Catalyst}} 3\text{R'CO}_2\text{-R} + \text{Glycerol} \quad \text{(overall reaction)}$$

The stepwise reactions are:

$$\text{Triglyceride} + \text{ROH} \underset{k_4}{\overset{k_1}{\rightleftharpoons}} \text{Di - glyceride} + \text{R'CO}_2\text{R}$$

$$\text{Di-glyceride} + \text{ROH} \underset{k_5}{\overset{k_2}{\rightleftharpoons}} \text{Mono - glyceride} + \text{R'CO}_2\text{R}$$

$$\text{Mono-glyceride} + \text{ROH} \underset{k_6}{\overset{k_3}{\rightleftharpoons}} \text{Glycerol} + \text{R'CO}_2\text{R}$$

The stepwise reactions are reversible and thus excess methanol was used to force the equilibrium to the product side. That is, the stochiometry of the reaction is such that oil to methanol ratio 1:6 is for better fuel yield. The potassium hydroxide was chosen as the base catalyst because of its low cost and easy accessibility. The methanol was chosen as the choice alcohol for the pre-treatment and transesterification process not only because it is economical but also because methanol easily reacts with triglycerides and the alkali catalyst easily dissolves in it (Ma and Hanna, 1999). The reaction temperature of 65˚C, 1.5%w/w of potassium hydroxide and three hours reaction was used as optimized in previous works (Meher et al., 2006; Sharma et al., 2008; Leung and Guo, 2006; Vincente et al., 2004).

The final biodiesel products, JAT3 and PAM3 were washed with warm distilled water and dried using sodium sulphate.

Characterization of JAT1, JAT3, PAM1 and PAM3

The percentage yield of JAT1 and PAM1 from the *Jatropha carcus* seeds and palm fruits respectively were determined. Similarly, the percentage yield of the biodiesel, (JAT3 and PAM3) from the corresponding oils, JAT1 and PAM1 were also obtained.

The relative density, acid value, saponification value, peroxide value, iodine value, and kinematic viscosity of JAT1, JAT3, PAM1, PAM3 l were determined using the standard methods . The cloud point, flash point and pour point temperatures of JAT1, JAT3, PAM1, PAM3 and petroleum diesel were obtained using the ASTM methods of testing.

Aliphatic hydrocarbon chromatographic and the spectrometric analysis of the crude oil samples and their biodiesel derivatives were carried out using a gas chromatography- mass spectrometer (GC-MS). A GC-MS device of the Agilent technology (gas chromatography) was used having a mass spectroscopy detector, 7890A & 5975C VLMSD and also equipped with an injector of model, 7683B. The column type was HP 5ms with dimension 30×0.250×0.25. The operation conditions used were set as follows; pressure- 15psi, flow rate- 4.511ml/min, heater- 285˚C, average velocity- 77.78cm/sec and volume injected-1µL.

RESULTS

JAT 1 is light yellow, JAT 3 is golden yellow. PAM 1 is reddish-orange and PAM 3 is orange. The colour can be altered by bleaching or addition of additive, depending on specification and desires. The percent yields of the oil and biodiesel for *jatropha carcus* and palm are as presented in Table 1. Table 2 shows the physico-chemical properties of *jatropha carcus* oil (JAT 1), biodiesel (JAT3), PAM 1, PAM 3 and petroleum diesel. The spectra obtained from the GC-MS analysis were presented in Figures 1 to 5.

Table 1: Percentage yield of the oil

No	Vegetable oil	Percentage oil yield	Percentage biodiesel yield
1	*Jatropha Curcas*	60.35%	75.33%
2	Palm Oil	35.08.%	63.63%

Table 2: Physico-chemical Properties of *Jatropha Curcas* oil (JAT 1), biodiesel (JAT 3), palm oil (PAM 1), Biodiesel (PAM 3) and petroleum diesel.

		Crude oil (JAT 1)	**Biodiesel (JAT 3)**	**Crude oil (PAM 1)**	**Biodiesel (PAM 3)**	**Petroleum diesel**
No	Properties	Value	Value	Value	Value	
1	colour	Light yellow	Golden yellow	Reddish- orange	Orange	Golden brown
2	Relative density	0.88	0.87	0.91	0.86	0.84
3	Kinematic viscosity mm^2/sec	27.11	4.80	39.60	4.40	3.60
4	Acid value (mgKOH/g)	6.73	0.49	3.00	0.08	0.28
5	Iodine value	102.6	93.0	97.0	60.1	-
6	Peroxide value	1.92	1.92	12.00	12.00	-
7	Flash point (^0C)	240	175	267	190	80
8	Cloud point (^0C)	16.00	13.00	31.00	20.00	0.14
9	Pour point (^0C)	8	8	15	15	10
10	Free Fatty Acid	3.37	0.25	1.50	0.04	-
11	Saponification value	193.6	190.0	207.0	106.5	29.4

DISCUSSION

The results obtained from the study of physical and chemical properties show that the percentage yield of the oil (JAT1) from *jatropha curcas* which is 60.35%, is higher than that of palm oil (PAM1) 35.08%. This reveals that *jatropha curcas* oil, not only being non- edible oil, would be a suitable feedstock for biodiesel producing industries compared to its palm oil counterpart. The percentage oil yield of palm oil also shows that it could also be a good feedstock for biodiesel producing industries, seeing it has a better oil yield than many other vegetable oil sources. For example, linseed and soybean having 33.33% and 18.53% percentage oil yield respectively (Gunstone, 1994). The high oil content of both *jaropha Curca*s seeds and palm oil indicates that they are also suitable feedstock in oleochemical industries (surfactants, detergents, soap and nitrogeneous derivatives).

The percentage yield of biodiesel from both oil sources is high, having 75.3% and 63.63% for *jatropha Curcas* and palm oil respectively. This indicates both oils are good sources for biodiesel. This is further illustrated in Figure 1.

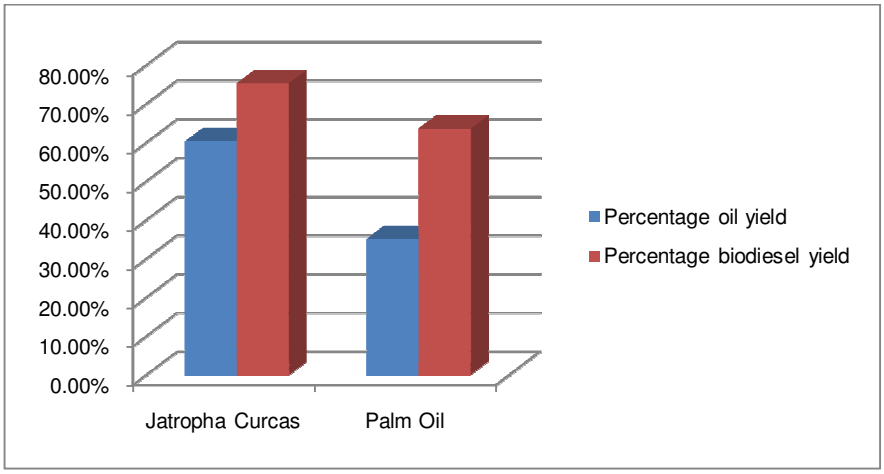

Figure 1: A chart representation comparing the percentage yield of both crude oil and the biodiesel derivative of *Jatropha Curcas* seeds and palm fruits.

The relative density from the experimental results (Table 2) showed that the respective oil produces a biodiesel of lower relative density with JAT1 having 0.8816, JAT3 having 0.8741 relative density. Similarly, PAM1 and PAM3 have relative densities 0.9130, and 0.8651 respectively. The ASTM D6751 (USA) and EN14214 (Europe) specifications for relative density show that only PAM 1 has a relative density higher than the specifications, making it a less suitable biofuel considering this parameter only (Figure 2).

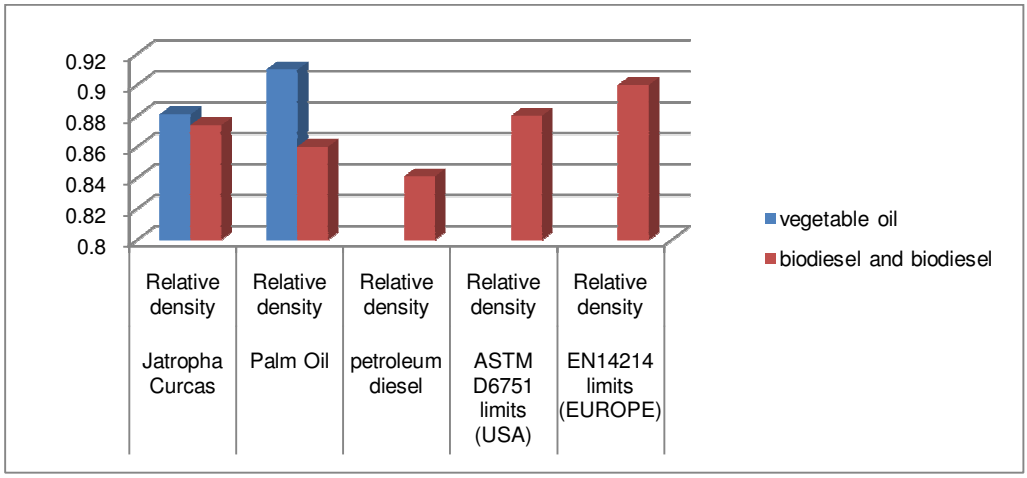

Figure 2: A chart representation comparing the acid relative densities of JAT 1, JAT 3, PAM 1, PAM 3, petroleum diesel, and ASTM D6751 & EN 14214 specifications.

Viscosity is defined as resistance of liquid to flow. Viscosity increases with molecular weight but decreases with increasing unsaturated level and temperature. The experimental results showed that JAT1 and PAM1 have higher viscosities than their corresponding biodiesel derivatives, JAT3 and PAM3. It also showed that PAM1 and JAT3 have higher viscosity compared to JAT1 and PAM3 respectively. High viscous oil is not suitable if it is used directly as engine fuel because it results in operational problems such as deposits, oil ring sticking and thickening/jelling as a result of contamination. *Jatropha Curcas* oil, JAT1 have an advantage over palm oil, PAM1 while and its biodiesel derivative, PAM3 have an advantage over JAT3, considering their kinematic viscosities. JAT3 and PAM3 viscosities fall within the range of specification for ASTM 6751 and EN 14214 standards while those of JAT1 and PAM1 oils were far above it (Figure 3).

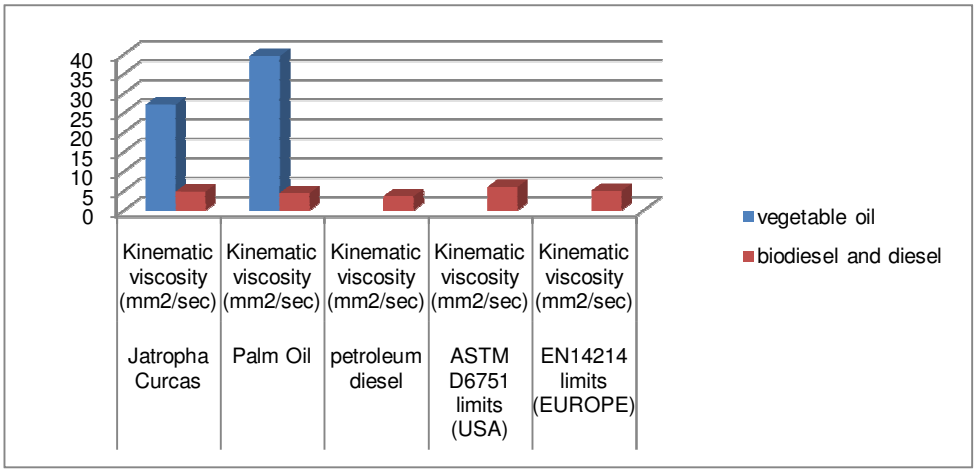

Figure 3: A chart representation comparing the Kinematic viscosities of JAT 1, JAT 3, PAM 1, PAM 3, petroleum diesel, and ASTM D6751 & EN 14214 specifications.

The Acid value and the free fatty acids (FFA) contents of both oils (JAT1 and PAM1) are high. *Jatropha curcas* oil and palm oil have acid values of 6.73 and 3.0 respectively (Tables 2). The FFA has a significant role to play especially in soap manufacturing process. The higher the FFA content the more suitable the oil for soap making. The high FFA content (greater than 1%w/w) will result into soap formation hence reducing the total biodiesel yield for the transesterification reaction defeating the objective of the reaction. Therefore the pre-treatment process which is the acid catalyzed esterification is employed to reduce FFA content. The acid catalyzed esterification of the oil into biodiesel is much slower than the base catalyzed trans-esterification reaction. The base catalyzed trans-esterification process will bring the reaction to a full completion by converting the triglycerides to methyl estsers and also neutralizing some of the remnant acidic constituents. The two step trans-esterification process was adopted (Veljkovic et al., 2006) and resulted in lower free fatty acid and acid values for the biodiesel derivatives which are 0.49 and 0.08 for JAT 3 and PAM 3 respectively. The acid values for the crude oil sources were above ASTM D6751 (USA) and EN14214 (Europe) specifications and biodiesel derivatives were below the maximum ASTM D6751 (USA) and EN14214 (Europe) specifications were plotted in Figure 4. It reveals that under the acid value parameter, the biodiesel derivatives (JAT3 and PAM 3) conform to the specifications in these regions.

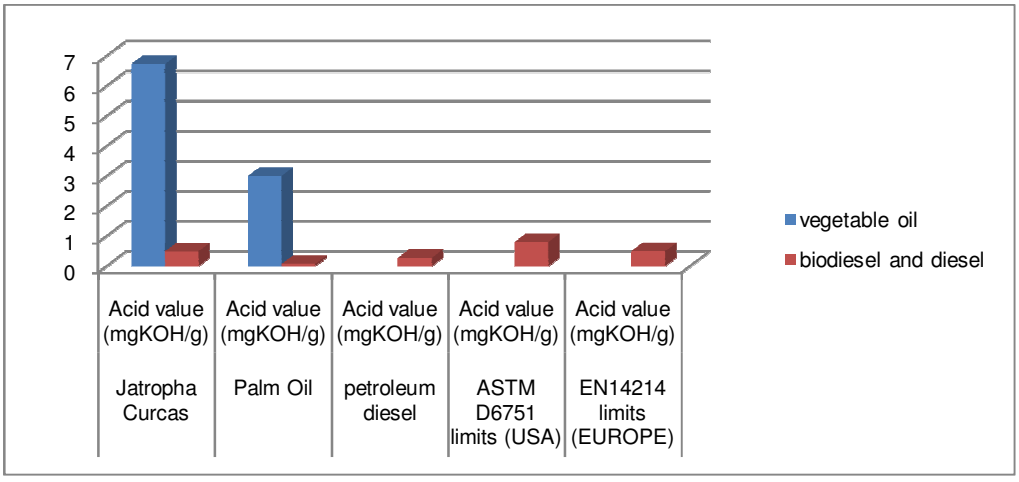

Figure 4: A chart representation comparing the acid values of JAT1, JAT3, PAM1, PAM3, petroleum diesel, and ASTM D6751 & EN 14214 specifications.

The saponification value revealed that JAT1 has a higher saponification value than PAM1. The saponification values of their corresponding biodiesel, JAT3 and PAM3 are lower than those of their oil sources JAT1 and PAM1. The saponification values for JAT 1 and PAM1 are 193.55 and 106.45 respectively while those for JAT3 and PAM3 are 190 and 207 respectively. High saponification value obtained for *Jatropha Curcas* oil shows the presence of normal triglycerides and are very useful in the production of liquid soap and shampoo (Emil et al., 2009).

The iodine value is a measure of unsaturation of fatty acids in fats and oils. JAT1 has a higher iodine value than PAM1. This shows the presence of high unsaturation in JAT1 oil. Higher iodine value indicates high unsaturation of fats and oils (Knothe, 2002; Kyriakidis and Katsiloulis, 2000). Lower iodine values 93 and 60 respectively, were observed in the biodiesel JAT3 and PAM3. The standard iodine value for biodiesel is 120 for Europe EN14214 specification. This means that JAT3 and PAM3 could serve as good biodiesel fuels. The reduction of unsaturated fatty acids is necessary due to the fact that heating higher unsaturated fatty acids results in polymerization of glycerides and can lead to the formation of deposits or lead to deterioration of the lubricating ability (Mittelbach, 1996). Higher unsaturated fatty acids are also likely to produce thick sludges in the pump of engine, when the fuel seeps down the sides of cylinder into crankcase (Gunstone, 2004). The higher unsaturation in JAT 1 may be due to higher content of unsaturated fatty acids such as oleic and linoleic acids as revealed by the GC-MS result. JAT 1 could be classified as a semi drying oil and PAM 1 as a non drying oil. The low peroxides values of JAT1 and PAM1 oils and their biodiesel derivative JAT 3 and PAM3 show degree of their oxidative stabilities. In the Figure 10, it could be seen that both oils and their biodiesel derivatives fall below 120, which is the maximum specification for EN14214. This shows that under the iodine value parameter both JAT1 and PAM1 oils and their corresponding biodiesel, JAT3 and PAM3 are suitable to be used as fuels.

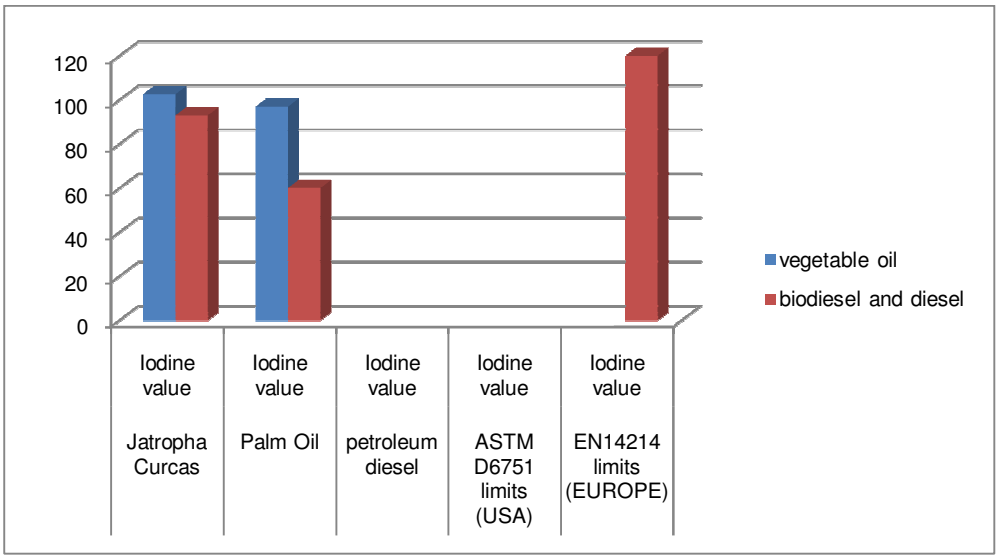

Figure 5: A chart representation comparing the iodine values of JAT 1, JAT 3, PAM 1, PAM3, petroleum diesel, and ASTM D6751 & EN 14214 specifications.

The flash point temperature of diesel fuel is the minimum temperature at which the fuel will ignite (flash) on application of an ignition source. Flash point varies inversely with the fuel's volatility. The high flash point temperatures of the oils (JAT1 and PAM1) and their biodiesel derivatives, JAT3 and PAM3, show that they all have very low flammability, which make them safer and better handled fuels. Figure 6 further illustrates this comparison

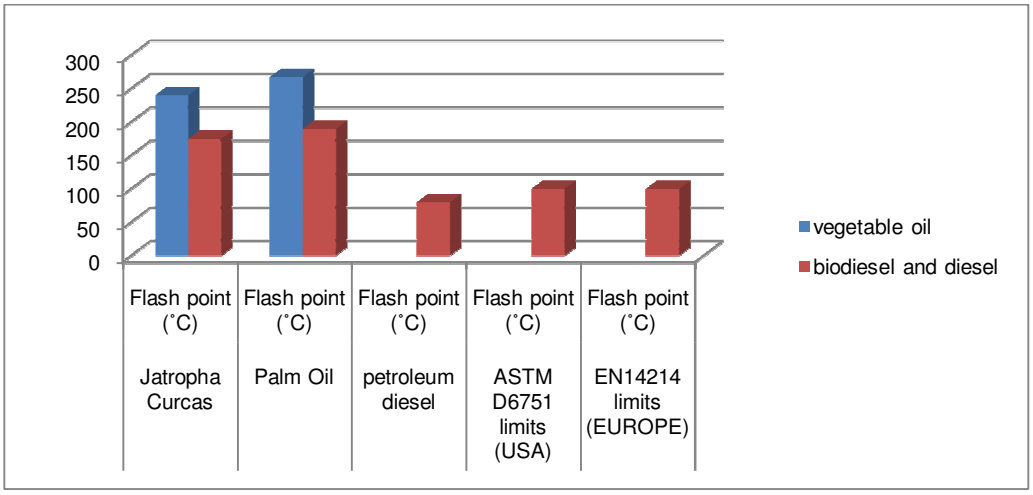

Figure 6: A chart representation comparing the flash points of JAT1, JAT3, PAM1, PAM3, petroleum diesel, and ASTM D6751 & EN 14214 specifications.

The cloud point of the oil sources (JAT 1 and PAM 1) and their biodiesel derivatives helps to indicate the temperature limit at which they could be used as fuel. The oils and biodiesel would not be suitable for usage as fuel in region where the temperature is lower than their cloud points because they start waxing or solidifying below these temperatures. In the light of this, *Jatropha curcas* oil having cloud point 16°C and its biodiesel derivative with 13°C cloud point has an advantage over palm oil with 31°C cloud point and its biodiesel derivative having cloud point of 20°C as illustrated in Figure 7.

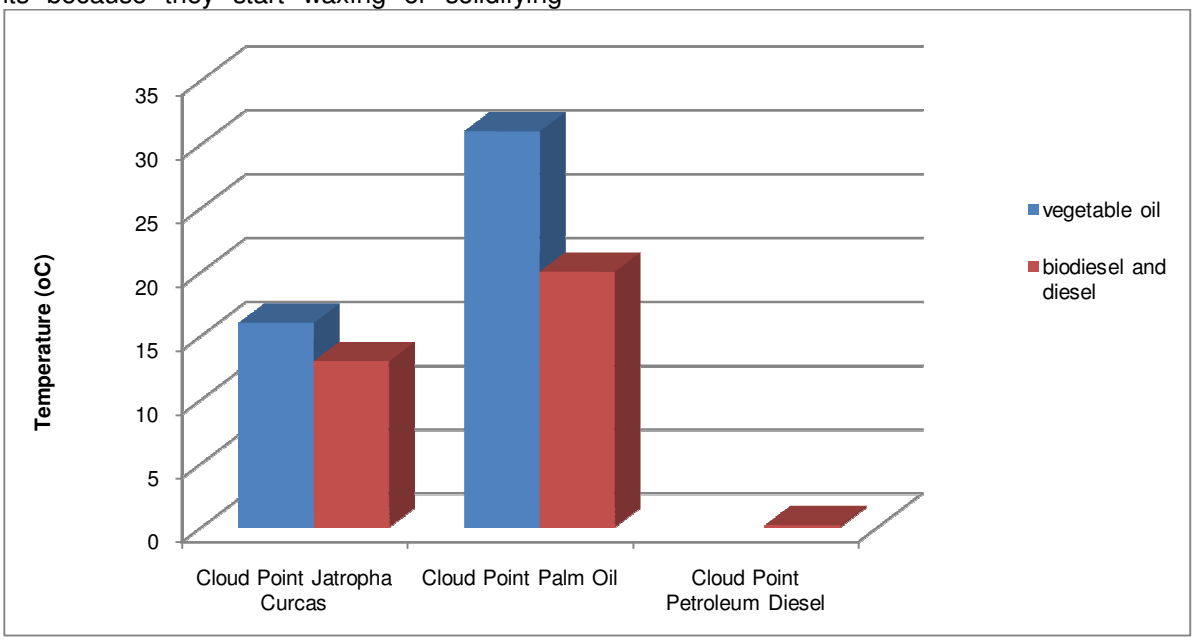

Figure 7: A Chart Comparing the Cloud Points of JAT1, JAT3, PAM1, PAM3 and Petroleum Diesel.

Melt or pour point refers to the temperature at which the oil in solid form starts to melt or pour. As illustrated in Figure 8, the pour point is the same for the vegetable oils and their biodiesel derivatives. The pour point of jatropha *curcas* oil and its biodiesel derivative fall in the range of ASTM D6751 and EN 14214 specifications. But palm oil and its biodiesel derivative were a bit higher than the limits. This shows that *Jatropha Curcas* oil and its

biodiesel derivative would be better biofuel option compared to palm oil and its biodiesel derivative.

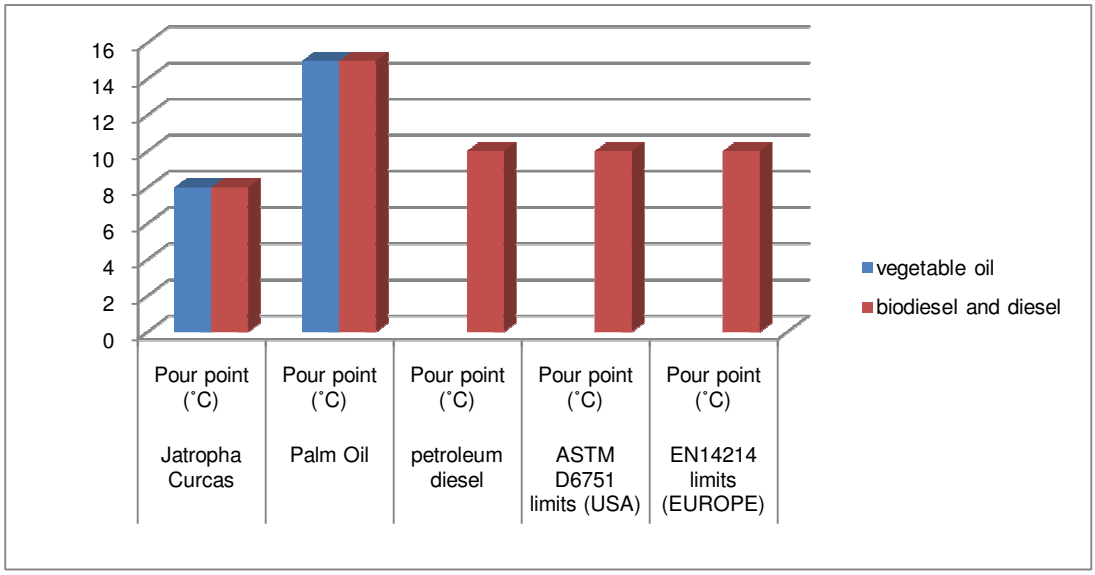

Figure 8: A chart representation comparing the pour points of JAT1, JAT3, PAM1 PAM3, petroleum diesel, and ASTM D6751 & EN 14214 specifications.

The copper strip corrosion test shows that JAT1 and PAM1 decolorized the copper strip which shows that they are corrosive. JAT3 and PAM3 has no effect on the copper strip. The corrosive action of JAT1 and PAM1 may be as a result of the presence of free fatty acids in them. The corrosive action of fuels has implications on storage and use of the fuel.

The GC-MS spectra were studied. Each spectrum was properly interpreted and outlined in Tables 3 to 7. Tables 3 and 4 show the interpretation of the spectra for the crude vegetable oils, JAT1 and PAM1 respectively. Tables 6 to 8 also show the spectra interpretation for the biodiesel JAT3, PAM3 and petroleum diesel respectively. From these tables, JAT1 and PAM1 constitutents include various fatty acids, namely, palmitic acid, stearic acid, oleic acid, and linoleic acid. Tables 5 and 6 confirmed the presence of fatty acid methyl esters as the major components of the biodiesels JAT3 and PAM3. This confirms the conversion of fatty acids in JAT1 and PAM1 by trans-esterification reaction into their respective biodiesel, the fatty acid methyl esters. It should be noted that the compounds confirmed by the GC-MS result interpretations were those of 90% quality assurance by the instrument.

As could be seen in Table 4 , the palm oil sample contains mainly oleic acid in excess of 16.86% peak area; though unusual but bearing in mind the limit used in preparing the table. And the least of the acid was stearic acid with 4.58% peak area.

Table 3 above contains the various components fou,nd in the jatropha curcas vegetable oil. These are mainly fatty acids; with oleic acid having the highest predominance as reflected in its percentage area of 41.72% and stearic acid present in the least amount of 4.78% in terms of peak area. The aldehyde (9, 17-Octadecadienal) present could, presumably, be formed from the rancidification of some of the unsaturated fatty acid component of the oil. It is also worthy of mentioning that there are equal number of saturated (palmitic and stearic) and unsaturated (linoleic and oleic) fatty acids. But the proportion of the unsaturated fatty acid is higher than that of the saturated fatty acid. The effectiveness of the employed method is reflected in Tables 5 and 6 as all the fatty acids present in the vegetable oil are converted to their methyl esters. In addition to these, a number of methyl esters of the original fatty acid isomers are also formed.

However, some methyl esters were found in the biodiesel samples with no corresponding fatty acids in their vegetable oil. This observation could be due in part to the fact that the corresponding fatty acids in the vegetable oils were not up to the minimum quality so as to be identified in the raw oils or they were formed during the trans-esterification process and thus their respective fatty acid methyl esters (FAMEs).

In contrast to the relatively simple FAME-dominated chemical composition of the biodiesel fuel samples, petroleum-derived diesel fuel had many more components. Petroleum-derived diesel fuel is composed primarily of hydrocarbon chains ranging in length from C8

to C20 and also commonly has aromatic compounds present. In general, petroleum-derived diesel fuel contains 65-85 vol. % aliphatic hydrocarbons, 5-30 vol. % aromatic hydrocarbons, and 0 to 5% olefins.

There are no FAME compounds present in petroleum-derived diesel fuel. The non-inclusion of the C8 to C20 straight chain aliphatic hydrocarbons in Table 7 may be due primarily to their not up to the 90 minimum quality used in preparing the table. Hence, it is not enough to say that they are not present in the petrol diesel sample here analyzed.

TABLE 3: GC-MS analysis of JAT 1

Retention time (min)	Name of compound	Percentage (%)	Common name
19.564	n-Hexadecanoic acid	8.94	Palmitic acid
21.647	9,17- Octadecadienal	22.21	-
21.693	9,12-Octadecadienoic acid	18.06	Linoleic acid
21.796	Oleic acid	26.37	Oleic acid
21.850	Oleic acid	15.35	Oleic acid
21.966	Octadecanoic acid	4.78	Stearic acid

TABLE 4: GC-MS analysis of PAM 1

Retention time (min)	Name of compound	Percentage (%)	Common name
19.704	n-Hexadecanoic acid	1.48	Palmitic acid
19.751	n-Hexadecanoic acid	3.11	Palmitic acid
19.804	Tridecanoic acid	3.75	
19.893	n-Hexadecanoic acid	8.14	Palmitic acid
21.737	Cis-9-Hexadecanoic acid	10.39	
21.783	Cis-3- Eicsenoic acid	3.66	
21.863	Cis-vaccenic acid	3.27	
21.946	Oleic acid	9.13	Oleic acid
21.989	Oleic acid	6.44	Oleic acid
22.059	Oleic acid	1.29	Oleic acid
22.069	Cis-13-Octadecenoic acid	3.25	
22.135	Cis-vaccenic acid	4.14	
22.202	Trans-13-Octadecenoic acid	9.37	
22.265	Octadecanoic acid	4.58	Stearic acid
28.087	Squalene	1.61	

TABLE 5: GC-MS analysis of JAT 3

Retention time (min)	Name of compound	Percentage (%)
18.913	Pentadecanoic acid methyl ester	0.45
19.149	Hexadecanoic acid methyl ester	5.02
20. 966	9,12-Octadecadienoic acid methyl ester	0.64
21.219	9,12-Octadecadienoic acid methyl ester	8.53
21.298	9,17-Octadecadienal	3.61
21.318	Trans-13-Octadecenoic acid methyl ester	1.98
21.351	9,12-Octadecadienoic acid methyl ester	3.90
21.385	15,Octadecenoic acid methyl ester	4.52
21.428	16,Octadecenoic acid methyl ester	6.71
21.494	10,Octadecenoic acid methyl ester	12.31
21.514	10, Octadecenoic acid methyl ester	4.78
21.541	11, Octadecenoic acid methyl ester	6.29
21.587	13, Octadecenoic acid methyl ester	10.62
21.604	12, Octadecenoic acid methyl ester	6.90
21.657	9, Octadecenoic acid methyl ester	14.70
21.773	Octadecanoic acid methyl ester	4.45
23.404	Eicosanoic acid methyl ester	0.06

TABLE 6: GC-MS analysis of PAM 3

Retention time (min)	Name of compound	Percentage (%)
18.917	Hexadecanoic acid methyl ester	0.13
19.216	Hexadecanoic acid methyl ester	4.89
19.276	Hexadecanoic acid methyl ester	2.32
19.299	Hexadecanoic acid methyl ester	1.51
19.322	Hexadecanoic acid methyl ester	1.06
19.352	Hexadecanoic acid methyl ester	2.74
19.395	Hexadecanoic acid methyl ester	1.02
19.422	Hexadecanoic acid methyl ester	1.53
19.518	Hexadecanoic acid methyl ester	5.80
19.548	Hexadecanoic acid methyl ester	6.36
19.621	Tridecanoic acid methyl ester	2.23
21.408	Cis-13-Octadecenoic acid methyl ester	10.29
21.853	6- Octadecenoic acid methyl ester	35.60

Table 6 continues

21.923	9- Octadecenoic acid methyl ester	8.70
21.953	9- Octadecenoic acid methyl ester	4.36
21.989	9- Octadecenoic acid methyl ester	5.40
22.086	Octadecanoic acid methyl ester	5.69
23.271	9-methyl Eicosanotate	0.08
23.527	Eicosanoic acid methyl ester	0.19
25.377	Docosanoic acid methyl ester	0.02
27.211	Tetracosanoic acid methyl ester	0.02

TABLE 7: GC-MS analysis of Petroleum diesel

Retention time (min)	Name of compound	Percentage (%)
4.754	4-methyl-1-ethyl benzene	0.11
12.081	Naphthalene	0.42
12.128	Naphthalene	1.02
12.367	Naphthalene	1.58
14.031	Naphthalene	2.06
14.204	Naphthalene	0.68
14.257	Naphthalene	0.43
21.674	(-) succinic anhydrid-2-Dodecen-1-yl	5.26
23.344	Indole	1.81
23.510	Cycloeicosane	1.35
23.650	1,2-Benzisothiazole	2.15

The experimental results obtained has clearly shown that based on the trans-esterification methods and conditions used , *Jatropha Curcas* oil is a better feedstock for biodiesel producing industries and other oleo chemical industries compared to the palm oil. *Jatropha Curcas* biodiesel can also serve as a more efficient and economical biofuel compared to its palm biodiesel counterpart.

Biodiesel is a clean-burning diesel fuel with a chemical structure of fatty acid alkyl esters. Of the various methods available for producing biodiesel, the alkali-catalyzed trans-esterification of vegetable oils and animal fats is currently the most commonly adopted method. Trans-esterification is basically a sequential reaction.

However, when the raw materials, oils or fats, contain a high percentage of free fatty acids or water, the alkali catalyst will react with the free fatty acids to form soaps and the water which can hydrolyze the triglycerides into diglycerides that can form more free fatty acids. These are undesirable reactions which reduce the yield of the biodiesel product. Therefore, using the two step trans-esterification process would help increase the biodiesel yield and make biodiesel production more economical.

Consequently, most of the physico-chemical properties determination carried out on biodiesel produced in the course of this research was found to fall within the range of American standard testing and method (ASTM D6751) and European standards (EN 14214) for biodiesel production. This will be of benefit to commercial biodiesel producers around the globe, who are looking for quality oils that are cheap and readily available.

References

Adebowale KO, Adedire CO, (2006). Chemical Composition and Insecticidal Properties of the Underutilized *Jatropha Curcas* Seed Oil. *African Journal of Biotechnology*, Vol. 5 (10), pp 901-906.

Boehman AL, (2005). Foreword biodiesel production and processing. *Fuel Process Technology.* 86: (10), 1057-1058.

Bozbas K, (2008). Biodiesel as an alternative motor fuel: Production and policies in the European Union. *Renewable and Sustainable Energy Reviews*, 12, 542–552

Du W, Xu Y, Zeng J, Liu D, (2004). Novozym 435-Catalysed Trans-esterification of Crude Soya Bean Oils for Biodiesel Production in a Solvent-Free Medium. *Biotechnology and Applied Biochemistry*, 40: 187–190

Emil Akbar, Zahira Yaakob, Siti Kartom Kamarudin, Manal Ismail, Jumat Salimon, (2009). Characteristic and Composition of *Jatropha Curcas* Oil Seed from Malaysia and its Potential as Biodiesel Feedstock Feedstock. European Journal of Scientific Research ISSN 1450-216X Vol.29: No.3 396-403.

Freedman B, Butterfield RO, Pryde E, (1986). Trans-esterification Kinetics of Soybean Oil. *Journal of American Oil Chemists Society.* 63: 1375-1380.

Fukuda H, Kondo A, Noda H, (2001). Biodiesel Fuel Production by Trans-esterification of Oils". *Journal of Bioscience and Bioengineering*. 92: (5), 405-416.

Gunstone FD, (2004). Rapeseed And Canola Oil: Production,Processing, properties and uses. London: Blackwell Publishing Ltd.

Gunstone FD, (1994). The chemistry of oils and Fats: Sources, composition, properties and uses. London: Blackwell Publishing Ltd.

Knothe G, (2002). Structure indices in FA chemistry. How relevant is the iodine value? *Journal of American Oil Chemists Soc*iety 9: 847–853.

Knothe G, (2006). Analyzing biodiesel: standards and other methods. *Journal American Oil Chemists Society* 83: 823–833.

Kyriakidis NB, Katsiloulis T, (2000). Calculation of iodine value from measurements of fatty acid methyl esters of some oils: comparison with the relevant American oil chemists society method. *Journal American Oil Chemists Society* 77:1235–1238.

Kumar A, Sharma S, (2008). An evaluation of mulipurpose oil seed crop for industrial uses (*jatropha curcas)*: A review. *Indsutrial Crops and Products*.

Leung DYC, Guo Y, (2006). Transesterification of neat and used frying oil: optimization for biodiesel production. *Fuel Processing Technology*; 87:883–90.

Ma F, Hanna MA, (1999).Biodiesel production: A review. *Bioresour Technol*; 70:1–15.

Meher LC, Vidya SS, Dharmagadda, Naik SN, (2006). Optimization of alkali catalyzed transesterification of Pungamia pinnata oil for production of biodiesel. *Bioresour Technol*; 97:1392–7.

Mittelbach M, (1996). Diesel fuel derived from vegetable oils, VI: specifications and quality control of biodiesel. *Bioresour Technol*; 56:7–11.

Noureddini H , Zhu D, (1997). Kinetics of Trans-esterification of Soybean Oil"*, Journal of Oil Chemists Society* 74: 11, 1457-1463

Openshaw Keith, (2000). A review of Jatropha curcas: an oil plant of unfulfilled promise. *Biomass and Bioenerg* 19: 1-15.

Pramanik K, (2003). Properties and use of jatropha curcas oil and diesel fuel blends in compression ignition engine. *Renewable Energy* 28: 239-248.

Schuchardt U, Sercheli R, Vargas RM, (1998). Tranesterification of Vegetable Oils: a Review, *Journal of Brazilian Chemical Society* 9: (1), 199-210.

Shaheed A, Swain E, (1998). Combustion Analysis of Coconut Oil and its Methyl Esters in a Diesel Engine", *I Mechanical Engineering Conference Transaction* 287-289.

Sharma YC, Singh B, Upadhyay SN, (2008). Advancements in development and characterization of biodiesel: A review. *Fuel*; 87:2355–73.

Solomons NW, (1996). Carotenes as dietary precursors of vitamin A: Their past and their future. *Sight and Life Newsletter* 3: 87-96.

Veljkovic´ VB, Lakicevic SH, Stamenkovic OS, Todorovic ZB, Lazic KL, (2006).
Biodiesel production from tobacco (*Nicotiana tabacum L.*) seed oil with a high content of free
fatty acids. *Fuel* 85: 2671–2675.

Vicente G, Martinez M, Aracil J, (2004). Integrated biodiesel production: a comparison of different homogeneous catalysts systems. *Bioresource Technology*; 92: 297–305.