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ORIGINAL RESEARCH ARTICLE

PRODUCTION AND CHARACTERIZATION OF BIODIESEL FROM HYBRID FEEDSTOCK OF *JATROPHA CURCAS* AND *THEVETIA PERUVIANA* SEEDS OIL

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ABSTRACT

This study elucidates one possible alternative to first generation feedstock used for biodiesel synthesis. The various conventional feedstock for biodiesel production have the conflict of competition as food sources which poses serious food security risks. Jatropha curcas and yellow oleander seed oils were subjected to in-situ hybridization process at different percentage blend compositions tagged: $Y_{90}J_{10}$, $Y_{80}J_{20}$, $Y_{70}J_{30}$, $Y_{60}J_{40}$ and $Y_{50}J_{50}$ before trans esterified to biodiesel. Biodiesel yields were found to be as high as 90.0, 86.1, 90.7, 92.2 and 88.2% for the hybrid blends $Y_{50}J_{50}$, $Y_{90}J_{10}$, $Y_{80}J_{20}$, $Y_{70}J_{30}$ and $Y_{60}J_{40}$ respectively. The optimal reaction temperature was 60°C, reaction time of 60 minutes, using 1% (w/w) KOH catalyst. Characterization of all synthesized biodiesel samples indicates fuel properties that are within the stipulated ASTM limits for fuel-grade biodiesels, except that high cloud points were observed in Y_{100} and J_{100}. The least cloud point was observed for biodiesel from hybrid oil blend $Y_{50}J_{50}$. The FTIR spectra of the fatty acid methyl esters of both oils and of their various blends confirms the presence of the major functional groups characteristics of bio-based diesel fuel.

1.0 Introduction

The increase in world population and industrialization have led to increase in global energy demand. Thus, necessitate the need to raise energy supplies in order to meet the demand. It was estimated that the total world energy consumption would increase by an average of about 2% per year from 2005 to 2025 (Sahoo *et al*., 2007). International Energy Agency (IEA) have indicated that the world will need 50% more energy in 2030 compared to 2019 demands, with an estimated 45% to be accounted for by China and India due to industrialization and population growth (Shahid and Jamal, 2011).

In addition, the continuous depletion of the world's crude oil reserves poses serious threat to global energy security and increase uncertainties in world energy markets. Consequently, the need for alternative fuel to conventional fossil-based fuel cannot be overemphasized for any nation's sustainable economic growth. For instance, in Nigeria, the over-dependence on oil imports for the transportation and agricultural sectors is a serious challenge that must be addressed. Hence, there is the urgent need to focus on potential sources for alternative energy for the development of renewable, biodegradable and environmentally friendly options like biofuel. The concept of biofuel is not new. Rudolph Diesel used vegetable oil (peanut oil) in a diesel engine in 1911 (Antczak *et al*., 2009; Akoh *et al*., 2007).

Biodiesel is a renewable, biodegradable, mono-alkyl esters of long chain fatty acids derived from renewable bio-lipids feed stock, such as oil or fat, through transesterification process, which produces an environmentally-friendly biofuel that conform to ASTM D6751 specifications suitable for application in compression ignition (CI) engines (Surma, 2008). Transesterification is the conversion of triglycerides into fatty acid alkyl esters (FAAE) and low molecular weight alcohols such as methanol and ethanol in the presence of catalyst (Demirbas, 2010; Sharma *et al*., 2008).

1.1 Feedstock for Biodiesel Synthesis

Biodiesel is produced using different kinds of oils comprising of both edible and non-edible vegetable oils, waste cooking oils, animal fats and algae oils (Mishra and Solanki, 2016) via a simple chemical procedure known as transesterification. The properties of biodiesel are categorized on the basis of various criteria; firstly, properties that relates to the processes taking place in the engine which includes: ignition qualities, ease of starting, fuel-air mixture formation, exhaust gas formation and heating value. Secondly, properties that relates to cold weather properties which includes: cloud point, pour point and cold filter plugging point. Thirdly, properties that relates to transport and depositing includes: oxidative stability, hydrolytic stability and flash point. Fourthly, properties that relates to wear of engine parts which includes: lubricity, cleaning effect, viscosity and compatibility with materials used to manufacture the fuel system (Barabás and Todorut, 2012).

Properties of feedstock for biodiesel vary depending on physico-chemical configuration and biological compositions. One possible way to improve these properties, and enhance biofuel yield, is hybridization of the feedstock. In addition, it has been reported (Eloka-Eboka and Inabao, 2014) that most of the developing countries including China and India are heavily relying on first generation biofuel production sources that also double as food sources. It is therefore necessary to explore some the nonedible sources available for the production of biofuels. Furthermore, there is abundance of forest and plant-based nonedible oils such as *jatropha curcas* (Jatropha), *azadirachta indica A. juss* (neem), *pongamia pinnata* (karanja), *madhuca indica* (mahua), *shorea robusta* (Sal), *hevea braziliensis* (rubber), and *trichilia emetic* (Natal Mahogany) in many sub-Saharan African countries, that can be exploited as substitute feedstock for biofuel manufacture (Ahmad *et al*., 2011).

Jatropha curcas plant has been widely studied and jatropha oil applied in biodiesel manufacture. Biodiesel synthesized from *Jatropha curcas* have similar chemo-physical, thermal, and engine performance properties to that of fossil-based diesel fuel, and was used as fuel without engine modification in compression-ignition (CI) engines. Nonetheless, the Jatropha biodiesel has some limitations including high viscosity which can only be used in CI engines when blended with diesel fuels in about 40-50% (Pramanik, 2003), high acid value above 5mg KOH/g (Minzangi *et al*., 2011). Zaku *et al*. (2012) reported *Jatropha curcas* oil acid value of 8.43 mg KOH/g; and therefore, need acid pretreatment before transterification to produce biodiesel. More also, the high cloud point of the oil can cause the biodiesels to gel in cold climates creating problem to engine operation (Dubey *et al*., 2011).

Yellow oleander (*Thevetia peruviana*) is an ever-green ornamental dicotyledonous shrub or small tree that belongs to the *apocynales* and *apocyanaceae* family (Dallatu *et al*., 2017). It is commonly found in the tropics and sub-tropics but it is native to central and south America. *Thevetia peruviana* made its way to Nigeria over fifty years ago, and has been grown as an ornamental plant in homes, public institutions and recreational areas (Ibiyemi, *et al*., 2002). It is a drought resistant plant, with yellow trumpet like flowers and grows well in all parts of Nigeria. It can be grown in arid zones as well as in higher rainfall zones and even on land with thin soil cover. It can withstand various ecological conditions provide the soil is well drained and is exposed to sunny area. In fact, it is a popular hedging and once established needs no care besides the annual pruning. It was reported (Dallatu *et al*., 2017) that yellow oleander have oil yield of up to 64.7% which is adjudged high yielding, this was supported by other workers that report oil yield of 60-65% (Basumatary, 2014). Unlike jatropha oil, yellow oleander oil does have limitations of high viscosity and cloud point (Dallatu *et al*., 2017).

1.2 Hybridization of the Feedstock

Hybridization of feedstock involves blending two or more different raw materials at varying proportions to produce resulting material that may have improved characteristic properties when compared to the parent stock (Eloka-Eboka and Inabao, 2014). The concept of hybridization of different feedstock can bring about better and improved qualities which single feedstock may not adequately present when used separately. When crude oils feedstock is blended together in the right proportions before biodiesel is produced via transesterification process, it is referred to as *in-situ* hybridization. The term *ex-situ* hybridization however, refers to when crude feed oils are initially converted to biodiesel before they are blended together.

2. Materials and Methods

Yellow oleander and *Jatropha curcas* seeds were purchased at National Institute for Chemical Technology NARICT Zaria, Kaduna State, Nigeria. The seeds were de-hulled manually, dried in an oven at 110°C for 1.5 hours and properly stored in polythene bags for further analysis.

2.1 Oil Extraction

Batch of 200g dried *Jatropha cau*cus and yellow oleander seeds were separately de-husked and then crushed into powder by the aid of mortar and pestle, and hand grinder separately, to increase surface area for enhance extraction. The powdered sample of both seeds were separately fed to a soxhlet extractor (150MLS, Glass; FINLAB) containing n-hexane which serves as the solvent; the system was connected to a 2l round bottom flask and a reflux condenser. The extraction was conducted for a period of 6 hours, at a temperature of 60°C after which the solvent was completely evaporated over a water bath condensed and recycled.

2.2 Characterization of *Jatropha Caucus* and Yellow Oleander Crude Oil

The following physico-chemical characteristics of *Jatropha* and yellow oleander seed oils were determined using ASTM standard procedures; acid value, saponification value, iodine value, free fatty acid, viscosity, density, specific gravity, refractive index and bulk density.

2.3 Hybridization of the Feedstock

The *in-situ* hybridization of *Jatropha caucus* seed oil and yellow oleander seed oils was adopted for biodiesel production blended in the percentage composition as follows: $Y_{100}J_0$, Y_0J_{100}, $Y_{50}J_{50}$, $Y_{90}J_{10}$, $Y_{80}J_{20}$, $Y_{70}J_{30}$, and $Y_{60}J_{40}$ from the crude oil samples. The subscripts for *Y*, represent the percent proportion of yellow oleander oil, while the subscripts for *J* represent the percentage proportion of jatropha oil. Firstly, each blend sample was placed in a homogenizer to mix the crude oils for 2 hours at 500 rpm at 60°C before transesterification process to produce the biodiesel.

2.4 Transesterification of the hybrid feedstock blends to biodiesel

The transesterification of the hybrid oils was carried out using methanol. The process was carried out according to ASTM standard procedure using methanol to hybrid oil mole ratio of 6:1. The reaction time was 1 hour, reaction temperature of 60°C and 1 % (w/w) KOH as a catalyst. Upon reaction completion, the mixture was allowed to cool at room temperature without agitation leading to a two-phase separation. The upper phase of the mixture was the hybrid oil methyl ester (HOME) i.e., the biodiesel and the lower phase consists of glycerol, excess methanol and catalyst, soap formed during the reaction, some entrained HOME and traces of glycerides. The two phases were separated by decantation. The HOME was washed with warm distilled water and dried at 100°C to remove any traces of water.

3. Results and Discussion

3.1 Characterization of yellow oleander and *jatropha curcas* seed oils

The yield of the oil from yellow oleander *(Thevetia peruviana*) seeds and *Jatropha Curcas* seed as well as their physicochemical properties are presented in Table 1. In this work the yield of yellow oleander and jatropha oils were 62.8%. and 53.97% respectively. This indicates that yellow oleander seed is high oil yielding, similar results (61.8%- 64.7%) are reported by Ibiyemi *et al*., (2002). However, the oil yield from *Jatropha curcas* also falls within the limit of 30-65% as reported by Azam *et al*., (2005). The yields from both oils show that both oils are viable feedstock for production of biodiesel. The oil yields of both seeds are higher than most of other non-edible oil producing seeds reported; like *Azadirachta indica* (44.5%), *Pangamia pinnata* (33%) and *Ziziphus mauritiana* (33%) (Azam *et al*., 2005).

Yellow oleander oil percent free fatty acid value (%FFA) was 1.295% while *Jatropha curcas* was 1.49%. The maximum free fatty acid value recommended by Canakci and Gerpen, (2001) for alkaline transesterification was 2 mg KOH/g above which acid pretreatment of the oil is necessary before transesterification. Therefore, both oils may also be considered for direct alkaline transesterification. Dorado *et al*., (2002) reported that the higher the free fatty acid in oil the less economical the oil is for the production of biofuels; this is because the oil will require added acid pretreatment before conversion to biodiesel that adversely affect the economic viability of the process. In addition, the high amount of free fatty acid favours the production of excess soap in the transesterification process which must be removed (Dorado *et al*., 2002; Ma *et al*., 1998). High oil acidity decreases yield of biodiesel by inhibiting the formation of methoxides thus neutralizing the catalyst present and producing soaps within the reaction medium.

The initial results showed 3.46 and 8.55 mg KOH/g acid value for yellow oleander and *Jatropha curcas* respectively. The high acid value found in yellow oleander and *Jatropha curcas* oils was an indication that the oils need acid pretreatment prior to its esterification to biodiesel. The high acid of *Jatropha curcas* oil in particular, means high level of free fatty acids which translates into decreased oil quality. Acid pretreatment was carried on both oils and the resulting acid values for yellow oleander and *Jatropha curcas* are 1.34 and 2.64 mg/KOH respectively. It is important to note that acid value is the most important property of a vegetable oil which depicts the quality, age and suitability for industrial processes such as production of biodiesel and bio lubricant (Akubugwo *et al*., 2008).

The lower acid value for yellow oleander seed oil compared to the jatropha oil implies that it contains less polyunsaturated fatty acids i.e., linoleic acid and linolenic acid (Khan *et al*., 2001). On the other hand, high acid value of jatropha seed oil will make it more susceptible to lipase action and will decompose faster than yellow oleander seed oil. However, these values were observed to be lower than those reported by (Minzangi *et al*., 2011) and (Zaku *et al*., 2012) for some non-edible oil seeds (*Azadirachta indica:* 17.40 mg KOH/g; *Ricinus communis:*12.48 mg KOH/g; *Moringa oleifera:* 4.96 mg KOH/g). The saponification value is an indication of the average length of the fatty acid chains which make up the oil.

Table 1: Physicochemical Properties of Yellow Oleander Seed and *Jatropha Curcas* Oils

Properties	Yellow oleander oil	*Jatropha curcas* oil
Oil yield (%)	62.8	53.97
Acid value (mg KOH/g) before acid pretreatment	3.46	8.55
Acid value (mg KOH/g) after acid pretreatment	1.34	2.62
Density(g/m^3)	0.870	0.920
Specific Gravity	0.905	0.924
Free Fatty Acid (%FFA)	1.30	1.49
Iodine Value (g/g)	74.6	101.84
Saponification Value (mg/g)	196.77	193.55

The saponification values in both yellow oleander and *Jatropha curcas* seed oils (196.77 and 193.55 mg/g respectively) are relatively high, this can be attributed to the high free fatty acid content in the oils (Hui, 1996). These values however, fall within the range of 182.5 – 260 mg/g reported by (Minzangi *et al*., 2011) for oils obtained from plant species. The higher saponification values recorded in both seed oil triglyceride is an indication of a larger number of short chain fatty acid molecules of low molecular weight, and accordingly consumes a larger number of moles of KOH.

In this work, the iodine value for yellow oleander seed oil (74.6g/g) and *Jatropha curcas* (101.83g/g) indicates stability to oxidation and are likely to be stored for a long period without becoming rancid due to the presence of high unsaturated fatty acids (Dallatu *et al*., 2017). Both oils therefore, are likely to be good feedstock in biodiesel industry.

The specific gravity of the yellow oleander and *Jatropha curcas* oil were 0.905 and 0.924 respectively. These values compare favourable with other results found for tropical African samples (Dawodu, 2009; Minzangi *et al*., 2011; Bhattacharya *et al.,* 2013). Generally, plant oils with specific gravity of 0.820 to 1.071 at 30°C are considered good for use as biofuels (Bhattacharya *et al.,* 2013; Minzangi *et al*., 2011).

3.2 Physico-chemical and fuel properties of the hybrid methyl esters

The effects of the hybridization on the physico-chemical and fuel properties of the synthesized biodiesels (pure oil methyl esters and hybrid oil blend methyl esters) are presented in the following sections. Generally, the respective methyl esters properties observed in this work were within the ASTM standards recommended limit (Gerpen *et al*., 2004) for fuel grade biodiesel and compare well with the conventional diesel.

3.2.1 Influence of hybridization on yield of hybrid methyl esters

The methyl esters yield of from all the oil samples investigated is presented in Figure 1. It can be seen that the average yield of hybrid methyl ester of all oil samples considered: $Y_{90}J_{10}$ (90% YO and 10% JO), $Y_{80}J_{20}$ (80% YO and 20% JO), $Y_{70}J_{30}$ (70% YO and 30% JO), $Y_{60}J_{40}$ (60% YO and 40% JO) and $Y_{50}J_{50}$ (50% YO and 50% JO), was approximately 90%. The highest biodiesel yield observed was from hybrid oil blend $Y_{70}J_{30}$ with 92.2%, and it can be observed that the least yield of biodiesel (J_{100}) was approximately 84%. All biodiesel yields were typical of methyl esters from other common oil seeds reported in the literature (Azam *et al*., 2005; and Kinast, 2003).

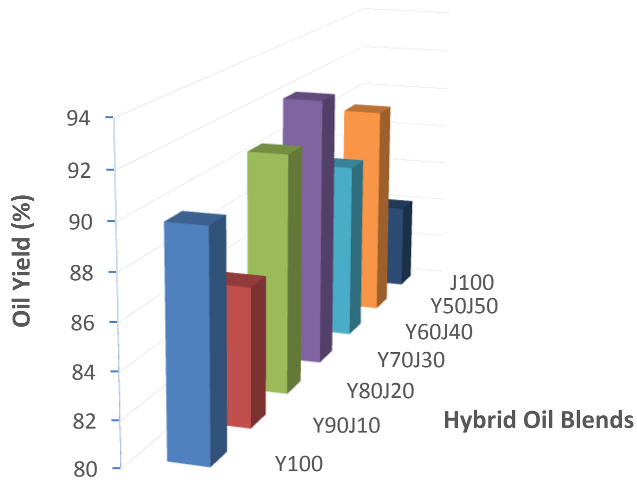

Figure 1: Influence of hybridization on yield of hybrid methyl ester

3.2.1 Influence of hybridization on specific gravity of hybrid methyl esters

The specific gravity measurement for the hybrid oil blends methyl esters compared to the methyl esters of the pure Y_{100} and J_{100} oils were presented in Figure 2. The values of the specific gravity of all hybrid methyl esters are conform to the ASTM standard (D1296) recommended limit of 0.88 (Ivase *et al*., 2015). It is important to note that the specific gravity of all the hybrid methyl esters were lower than that of the J_{100} (0.96) which is slightly higher than the recommended ASTM limit. This may likely be due to high entrained moisture content in the parent J_{100} oil.

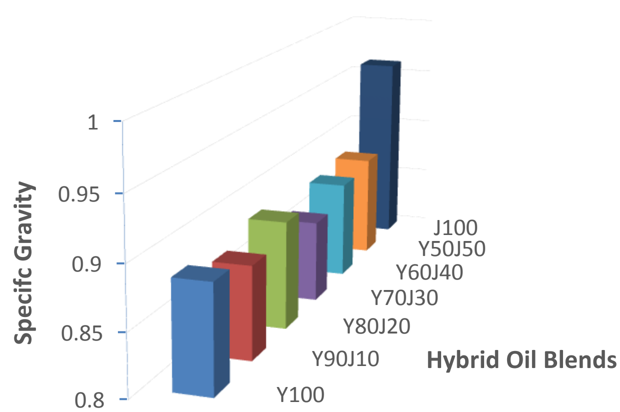

Figure 2: Influence of hybridization on specific gravity of hybrid methyl ester

3.2.2 Influence of hybridization on the viscosity of hybrid methyl esters

The effect of the hybridization on the viscosity of the hybrid methyl esters is shown in Figure 3. The viscosity is a critical parameter of the injection property of the biodiesel. Too high viscosity leads to clogging of the injector of the CI engines. The ASTM standard (D445) of the viscosity recommended limit of biodiesel is 1.9-6.5 mm/s^2 (Kinast, 2003). All the hybrid biodiesel produced have viscosity in the range of the ASTM standard. Worth noting is that the hybrid methyl ester from hybrid oil blend $Y_{70}J_{30}$ has the least viscosity of about 2.0cSt. which makes it most suitable for fuel injection applications.

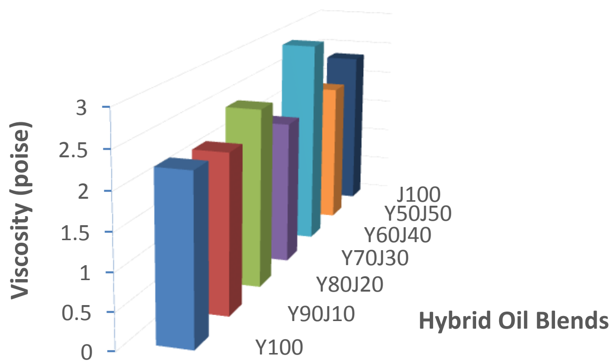

Figure 3: Influence of hybridization on viscosity of hybrid methyl ester

3.2.2 Influence of hybridization on cloud point of hybrid methyl esters

The cloud point profile of the synthesized biodiesels is shown in Figure 4. It could be noted that the cloud point values of all hybrid methyl esters are within the recommended ASTM standard (D975) recommended limit of -3°C to 12°C. The cloud point values of all hybrid methyl esters are lower than that of the methyl esters from pure oils (Y_{100} and J_{100}. The cloud point values of the biodiesel from Y_{100} and J_{100} are higher than the biodiesels from the hybrid oil blends. The high values for the pure biodiesels cloud points (Y_{100}; 12°C and J_{100}; 10°C) are due to high composition of oleic acid. The cloud point is critical in cold weather performance of the biodiesel, hence the high cloud point of the methyl esters of the pure oils may limit their use as fuel in cold climates. In Nigeria the FAME of yellow oleander and *Jatropha curcas* will tend to retain their flow properties due to relatively warm climate, but they would tend to precipitate wax under the condition where the ambient temperature is just a little above the cloud point.

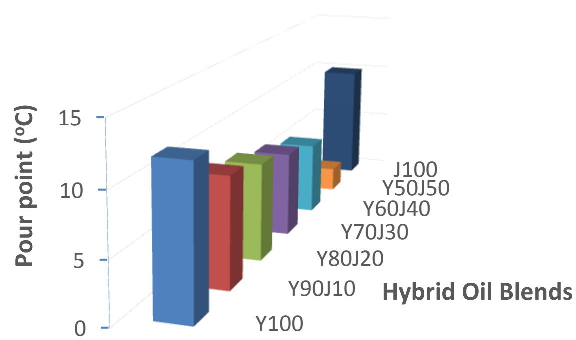

Figure 4: Influence of hybridization on viscosity of hybrid methyl ester

3.2.2 Influence of hybridization on other fuel properties

The pour point and the refractive index of the synthesized methyl esters are presented in Table 2. The pour point is the property of the biodiesel that defines its ability to flow before it can be gelled. It is a measure of the temperature below which the fuel cease to flow. Fuels with high pour point are relatively difficult to be used in areas with lower temperatures, because the biodiesel must be kept relatively warm to retain its flow capabilities by some external means such as electric heaters, tanks or flow line insulations, for instance.

All biodiesels have relatively high pour points than conventional diesel in the region of over 20°C (Kinast, 2003). All the methyl esters produced in this work exhibit pour point characteristic higher than some common vegetable oil methyl esters (example, soya oil, canola oil, moringa oleifera oil, palm oil, etc.) as reported in the literature (Kinast, 2003; Ivase *et al.*, 2015; Zubairu and Ibrahim, 2004).

Table 2: Physicochemical and Fuel Properties of the Produced Biodiesels and Hybrid Blends.

	Y_{100}	$Y_{90}J_{10}$	$Y_{80}J_{20}$	$Y_{70}J_{30}$	$Y_{60}J_{40}$	$Y_{50}J_{50}$	J_{100}	Petro. Diesel
Pour point (°C)	3	3	4	4	2	-5	6	-16
Refractive index	1.447	1.449	1.366	1.448	1.449	1.451	1.453	-

3.3 Fourier transform infra-red spectroscopy

The jatropha oil, yellow oleander oil and hybrid oil blends biodiesels were subjected to Fourier Transform Infrared Spectroscopy (FTIR) to characterize and emulate the presence of various carbon isomers. As a representative example, the FTIR spectra of the methyl ester of the oil blend Y70J30 is shown in Figure 5.

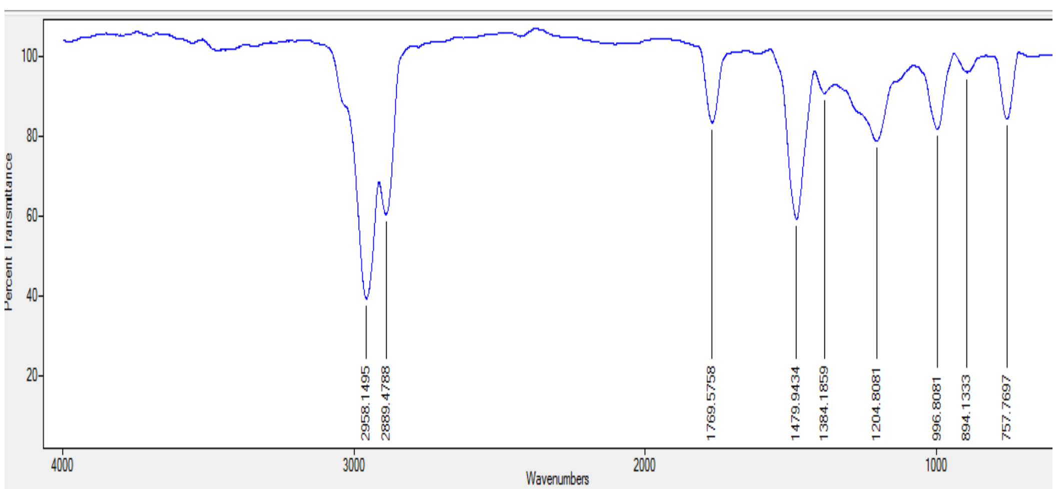

Figure 5: FTIR Spectrum of $Y_{70}J_{30}$ methyl ester

The FTIR analyses of the yellow oleander methyl ester (YOME), and jatropha methyl ester (JOME) and hybrid oil blends methyl esters showed the region 745.08 cm^{-1}–998.52 cm^{-1} indicate the presence of =C-H functional groups. They possess bending type of vibrations appearing at low energy and frequency region in the spectrum and are all double bounded. The spectra also confirm the presence of carbonyl functional group at 1764.73 to 1772.55 cm^{-1} as the most intense and prominent bands. They are part of fatty acid methyl esters with unsaturated bond in the biodiesel, such as methyl oleate and methyl linoleate. Methyl oleate was also reported by Saifuddin, (2014) in this region. The carbonyl (-C=O vibration) group of esters showed strong absorption bands at 1764.73 to 1772.55 cm^{-1} in the FTIR spectra of the biodiesels, also indicate the presence of fatty acid methyl esters. This group indicates the conversion of triglycerides in the oil to methyl esters.

The Summary of the FTIR spectra of biodiesel from jatropha oil, yellow oleander oil and hybrid oil blends are shown in Table 3.

Table 3: Summary of the FTIR Spectra Peaks (cm^{-1}) of the Pure Oils Methyl Esters and Hybrid Oil Blend Methyl Esters

Wave Number (cm^{-1})	Assignment
2887.21	Region of hydrogen's stretching.
3651.72	-OH stretching vibration of the triglycerides
	-Symmetric and asymmetric stretching vibration of the aliphatic $–CH_2$ and $-CH_3$ group.
1764.73	Region of double bond's stretching
1772.55	-ester carbonyl functional group of the triglycerides
	-C=C stretching vibration of olefins
-	Region of other bonds deformations and bendings
	- Bending vibrations of $-CH_2$ groups
745.08	Fingerprint region
998.52	-C-O stretching vibration of ester group
	- CH_2 rocking vibration and the out of plane vibration of disubstituted olefins

3.3 Gas Chromatography Mass Spectroscopy GC-MS

T$_o$ investigate the presence of FAMEs in the produced biodiesel samples; yellow oleander oil (Y_{100}), jatropha oil (J_{100}) and the respective hybrid oil blends ($Y_{90}J_{10}$, $Y_{80}J_{20}$, $Y_{70}J_{30}$, $Y_{60}J_{40}$, $Y_{50}J_{50}$) were subjected to GC–MS analysis, the detail result for the methyl ester of the Y70J30 oil blend; as a representative example is presented in Figure 6.

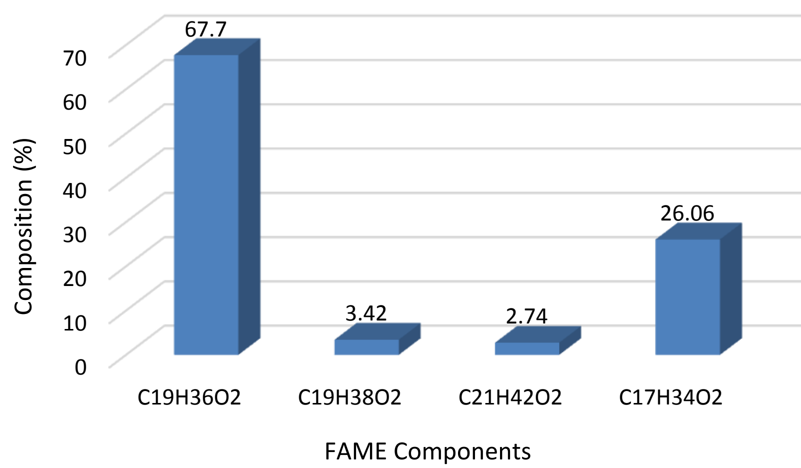

Figure 6: Chemical composition of Hybrid blend Y70J30 Biodiesel

The respective AMEs were identified by comparing the mass spectrum of each component with spectra in the National Institute of Standards and Technology (NIST) mass spectral library. We used the GC spectrum and confirm some major peaks as the dominant peaks in the respective biodiesels, which are consistent with previous literature (Ahmad, *et al*., 2011). The major identified FAMEs present in the hybrid methyl esters include: hexadecanoic acid, methyl ester; 9(Z)-hexadecenoic acid, methyl ester; methyl stearate; 9(Z)-octadecenoic acid, methyl ester; eicosanoic acid, methyl ester and docosanoic acid, methyl ester.

4. Conclusion

Crude oils were extracted from yellow oleander and *Jatropha curcas* seeds using solvent extraction method. The oil yield was 62.8% and 53.97% for yellow oleander and jatropha seed respectively. Characterization of the oils indicates iodine values of 74.6g/g for yellow oleander and 101.83g/g for *Jatropha curcas*. The oils were adjudged to have stability to oxidation and are likely to be stored for a long period without becoming rancid due to the presence of high unsaturated fatty acids. All physicochemical properties of the oils are within ASTM recommended limits.

Synthesized biodiesel yields from the oils are 89.8% and 84.1% for yellow oleander and *Jatropha curcas* respectively. Similarly, the biodiesel yields from the hybrid oil blends were 90.0, 86.1, 90.7, 92.2 and 88.2% for hybrid oil blends $Y_{50}J_{50}$, $Y_{90}J_{10}$, $Y_{80}J_{20}$, $Y_{70}J_{30}$ and $Y_{60}J_{40}$ respectively. Characterization of all synthesized biodiesel samples indicates fuel properties that are within the stipulated ASTM limits for fuel-grade biodiesels, except that high cloud points were observed in Y_{100} and J_{100}. The least cloud point was observed for biodiesel from hybrid oil blend $Y_{50}J_{50}$. The FTIR spectra of the fatty acid methyl esters of yellow oleander oil and *Jatropha curcas* oil, as well as fatty acid methyl esters of the various blends of the oils synthesized confirms the presence of the major functional groups characteristics of bio-based diesel fuel.

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